(NASA-CP-10083-Vol-1-Pt-1) BEYOND THE BASELINE 1991: PROCEEDINGS OF THE SPACE STATION EVOLUTION SYMPOSIUM. VOLUME 1: SPACE STATION FREEDOM, PART 1 (NASA) 336 p
CSCL 22B G3/18
N92-17098
--THRU--
N92-17112
Unclas
0062381

NASA Conference Publication 10083

Beyond the Baseline 1991

Proceedings of the Space Station Evolution Symposium

Volume 1: Space Station Freedom

Part 1

Proceedings of a conference held at South Shore Harbour Resort and Conference Center League City, Texas August 6-8, 1991

NASA

NASA Conference Publication 10083

Beyond the Baseline 1991

Proceedings of the Space Station Evolution Symposium

Volume 1: Space Station Freedom

Part 1

Proceedings of a conference held at South Shore Harbour Resort and Conference Center League City, Texas

NASA

National Aeronautics and Space Administration

Scientific and Technical Information Branch

1991

Preface

This publication is a compilation of papers presented at the Second Space Station Evolution Symposium: "Beyond the Baseline 1991" from August 6 - 8, 1991. The symposium was structured as a forum to discuss the current status and future plans for Space Station Freedom (SSF). The primary purpose of the gathering was to review the plans and progress in ensuring a baseline design with the flexibility to accommodate a broad range of potential utilization demands and to effectively incorporate technology advances over the lifetime of the facility. The timing of the conference was chosen at the critical juncture between completion of the Delta Preliminary Design Reviews and the Program Critical Design Reviews.

The plenary papers describe the current status of the restructured Space Station Freedom design, the plans of the international partners, and future utilization of the facility. Related programs in advanced technology and space transportation are also discussed.

The technical sessions represent the results of tasks funded by Level I Space Station Engineering in Advanced Studies and Advanced Development. The charts presented are amplified here by facing page text. The work was accomplished in fiscal years 1990 and 1991 and was presented by those in government and industry who performed the tasks.

The results of SSF Advanced Studies provide a road map for the evolution of Freedom in terms of user requirements, utilization and operations concepts, and growth options for distributed systems. Regarding these specific systems, special attention is given to: highlighting changes made during restructuring; description of growth paths through the follow-on and evolution phases; identification of minimum-impact provisions to allow flexibility in the baseline, and identification of enhancing and enabling technologies.

The activities under Advanced Development and Engineering Prototype Development (EPD) are targeted to improve the functionality and performance of baseline systems, thus providing options to the program which reduce schedule and technical risks. These applications have the potential to improve flight and ground system productivity, reduce power consumption and weight, and prevent technological obsolescence. Products of these tasks include: "Engineering" fidelity demonstrations and evaluations of advanced technology; detailed requirements, performance specifications, and design accommodations for insertion of advanced technology, and mature technology, tools, and applications for SSF flight, ground, and information systems.

Dr. Earle K. Huckins, III
Director, Space Station Engineering
Office of Space Flight
NASA Headquarters

Listed below are the persons who made this symposium possible.

COMMITTEE MEMBERS

Conference Chair:

- Earle K. Huckins III
  NASA Headquarters

Program Planning Committee Technical Chairs:

- Stephen Cook
  NASA Headquarters
- Gregg Swietek
  NASA Headquarters
- Mark Gersh
  NASA Headquarters
- Peter Ahlf
  NASA Headquarters
- Alan Fernquist
  NASA Headquarters

Session Chairs:

- Lewis Peach
  NASA Headquarters
- John-David Bartoe
  NASA Headquarters
- W. Ray Hook
  NASA Langley Research Center
- Karen Brender
  NASA Langley Research Center
- Edward Chevers
  NASA Ames Research Center
- Gregg Swietek
  NASA Headquarters
- Mark Gersh
  NASA Headquarters
- Alan Fernquist
  NASA Headquarters

Administrative Co-Chairs:

- Glenn Freedman
  UH-Clear Lake
- Carla Armstrong
  Barrios Technology, Inc.

CONTENTS – Volume 1

Title Page

Part 2

SESSION II: EVOLUTION CONCEPTS AND OPERATIONS
SESSION CHAIR: MS. KAREN BRENDER, NASA LANGLEY RESEARCH CENTER

SESSION III: SPACE STATION DATA SYSTEMS
SESSION CHAIR: MR. EDWARD CHEVERS, NASA AMES RESEARCH CENTER

Time	Topic	Presenter
Tuesday August 6, 1991		
8:30 - 12:00	PLENARY SESSION 1 — OUTLOOK FOR SPACE STATION FREEDOM Session Chair: Dr. Earle K. Huckins III *NASA Headquarters*	
8:30	Welcoming Remarks	Dr. Aaron Cohen *Director, NASA Johnson Space Center*
8:45	Space Station Freedom: An Investment In The Future	Dr. William B. Lenoir *Associate Administrator, NASA Office of Space Flight*
9:45	Space Station Freedom Program Status	Dr. John Cox *Deputy Manager for Operations* *Space Station Freedom* *Program and Operations*
10:15	Break	
10:30	Columbus Programme	Mr. Derek Dell *ESA Representative* *Space Station Freedom Program and Operations*
11:00	Japanese Experiment Module	Mr. Kazuhiko Yoneyama *Director, Space Station Group* *Space Station Program Department NASDA*
11:30	Canadian Space Station Program	Mr. Karl Doetsch *Director General, Space Station Program* *Canadian Space Agency*
12:00 - 1:30	Lunch	
1:30 - 5:30	PLENARY SESSION 2 — FUTURE SPACE PROGRAMS AND PLANS Session Chair: Mr. Lewis L. Peach *NASA Headquarters*	
1:30	Space Station Freedom Evolution	Dr. Earle K. Huckins III *Director, Space Station Engineering* *NASA, Office of Space Flight*
2:00	SEI: An Update	Mr. Lewis Peach Assistant *Director for Space Exploration, NASA Office of Aeronautics, Exploration and Technology*
2:30	Advanced Space Transportation Systems	Mr. Robert Davies *Chief, Advanced Transportation Planning* *NASA, Office of Space Flight*
3:15	National Aero-space Plane	Dr. H. Lee Beach, Jr. *Director for National Aero-Space Plane, NASA Office of Aeronautics, Exploration and Technology*
3:45	Break	

Time	Topic	Presenter

Tuesday August 6, 1991 *(continued)*

PLENARY SESSION 3 — FUTURE UTILIZATION OF SPACE STATION FREEDOM
Session Chair: Dr. John-David Bartoe
NASA Headquarters

4:00	Commercial Opportunities During Space Station Freedom Evolution	Mr. Richard Ott *Director, Commercial Development Division* *Office of Commercial Programs*
4:30	Technology Development on the Evolution Space Station	Dr. Judith Ambrus *Assistant Director for Large Space Systems* *NASA Office of Aeronautics, Exploration and Technology*
5:00	Expanded Research and Development on Space Station Freedom	Dr. Edmond M. Reeves *Deputy Director, Flight Systems Division* *NASA Office of Space Science and Applications*

Wednesday August 7, 1991

8:00 - 11:45 STRATEGIES FOR EVOLUTION
Session Chair: Mr. W. Ray Hook
NASA Langley Research Center

8:00	A Historical Perspective on Space Station	Mr. W. Ray Hook *Director for Space,* *NASA Langley Research Center*
8:30	MIR: A Case Study for Evolution	Dr. B. J. Bluth *Technical Assistant to the Deputy Director, Space Station Freedom Program and Operations*
9:30	Break	
9:45	Space Station Advanced Studies	Mr. Peter Ahlf *Manager, Advanced Studies,* *NASA Space Station Engineering* *NASA, Office of Space Flight*
10:15	Space Station Advanced Development	Mr. Alan Fernquist *Manager, Advanced Development* *NASA Space Station Engineering* *NASA, Office of Space Flight*
10:45	Commercial Aspects of Space Station Freedom	Mr. Kevin Barquinero *External Programs Manager,* *NASA Space Station Engineering* *NASA, Office of Space Flight*

Time	Topic	Presenter
Wednesday	**August 7, 1991** *(continued)*	
11:15	Evolution Design Requirements and Design Strategy	Mr. Donald Monell *Space Station Freedom Office,* *NASA Langley Research Center*
11:45	Lunch	
1:30 - 4:45	PARALLEL SESSION: EVOLUTION CONCEPTS AND OPERATIONS Session Chair: Ms. Karen Brender *NASA Langley Research Center*	
1:30	Baseline Operations Concept	Mr. Granville Paules *Space Station Operations and Utilization* *NASA, Office of Space Flight*
2:00	Astronaut Scientific Associate	Mr. Silvano Colombano and Michael Compton *NASA Ames Research Center*
2:30	Growth User Requirements for Space Station Evolution	Mr. Kevin Leath *McDonnell Douglas Space Systems Co.,* *Washington SE & I*
3:00	Break	
3:15	SSF Growth Concepts & Configurations	Mr. William Cirillo *Space Station Freedom Office,* *NASA Langley Research Center*
3:45	STV Fueling Options	Mr. Kenneth Flemming *McDonnell Douglas Space Systems Co.,* *Kennedy Space Division*
4:15	A Safety Analysis of Cryogenic Propellant Handling on SSF	Mr. Sam Dominick *Martin Marietta* *Astronautics Group*
1:30 - 4:30	PARALLEL SESSION: SPACE STATION DATA SYSTEMS Session Chair: Mr. Edward Chevers *NASA Ames Research Center*	
1:30	Advanced DMS Architectures	Mr. Ed Chevers *NASA Ames Research Center*
2:15	Optical Protocols for Advanced Spacecraft Networks	Dr. Larry Bergman *NASA Jet Propulsion Laboratory*
2:45	Break	
3:00	Advanced Portable Crew Support Computer	Ms. Debra Muratore *NASA Johnson Space Center*
3:30	ISE Advanced Technology	Mr. Barry R. Fox *NASA Johnson Space Center*

Time	Topic	Presenter

Wednesday August 7, 1991 *(continued)*

4:00	Real-Time Data Systems	Mr. Troy Heindel *NASA Johnson Space Center*
4:30	Computer System Evolution Requirements for Autonomous Checkout of Exploration Vehicles	Mr. Mike Sklar *McDonnell Douglas Space Systems Company* *Kennedy Space Division*

Thursday August 8, 1991

8:00 - 11:45

PARALLEL SESSION: DISTRIBUTED SYSTEMS
Session Chair: Mr. Gregory Swietek
NASA Headquarters

8:00	Advanced Photovoltaic Power Generation	Mr. Edward Fisher *Boeing Defense and Space Group* *Huntsville, Alabama*
8:25	Advanced Solar Dynamic Power Systems	Mr. Michael Zernic *NASA Lewis Research Center*
8:45	Power Management and Distribution Evolution	Mr. Michael Zernic *NASA Lewis Research Center*
9:05	Solar Alpha Rotary Joint Capability Enhancement	Mr. David Snyder *Lockheed Missiles and Space Company*
9:30	Power Management and Control Automation	Mr. James Dolce *NASA Lewis Research Center*
10:00	Power Management and Distribution Automation	Mr. Louis Lollar *NASA Marshall Space Flight Center*
10:30	Break	
10:45	Active Thermal Control System Evolution	Ms. Patricia Petete *NASA Johnson Space Center*
11:15	Thermal Control System Automation	Mr. Roger Boyer *McDonnell Douglas Space Systems Company*
11:45	Lunch	

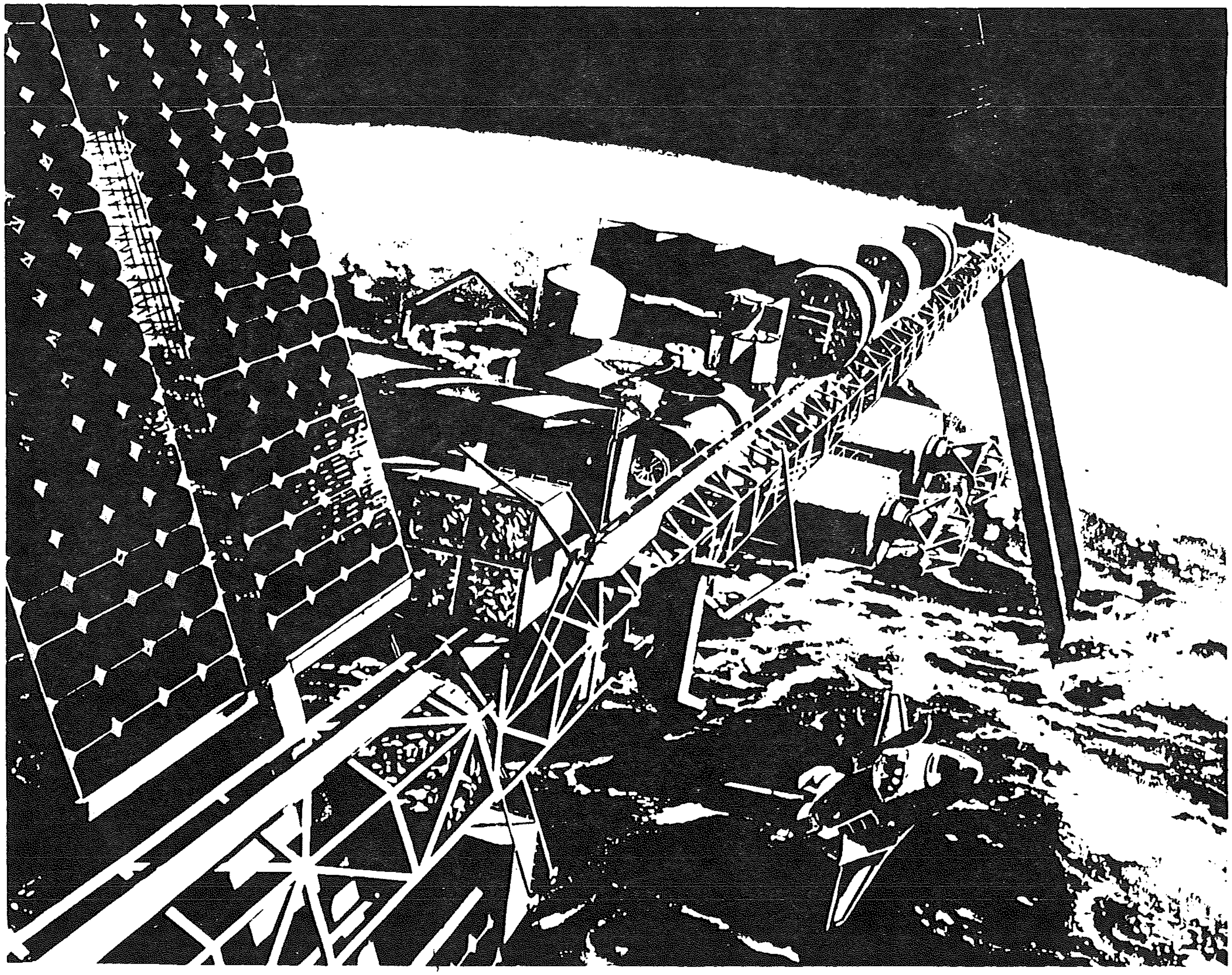
8:30 - 11:45

PARALLEL SESSION: ENGINEERING TOOLS AND TECHNIQUES
Session Chair: Mr. Mark Gersh
NASA Headquarters

8:30	Failure Environment Analysis Tool	Mr. Dennis Lawler *NASA Johnson Space Center*
9:00	Space Station Freedom Software Reconfiguration	Mr Larry Grissom and Bryan Porcher *NASA Johnson Space Center*

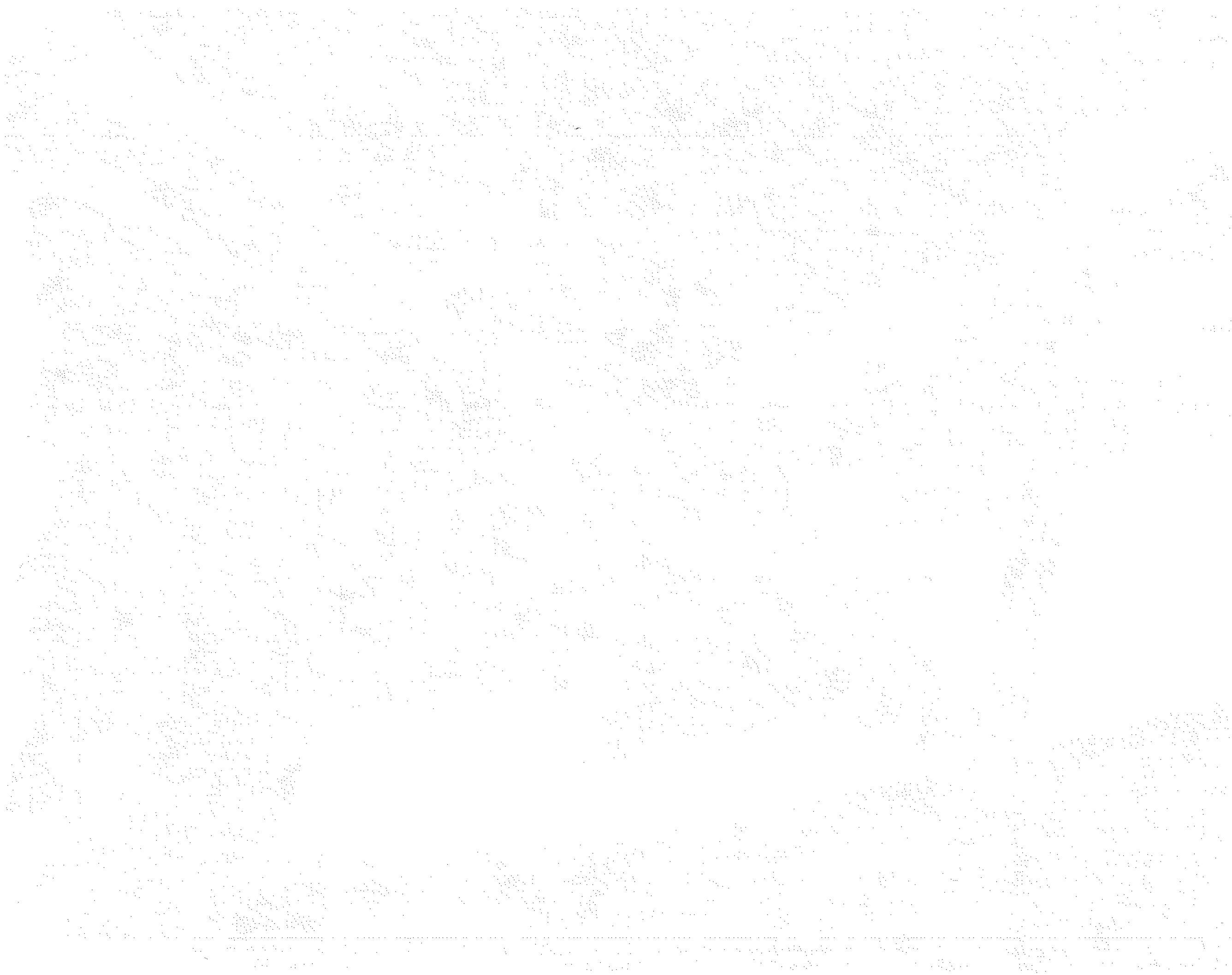
Time	Topic	Presenter
Thursday	**August 8, 1991** *(continued)*	
9:30	Software Life Cycle Methodologies & Environments	Mr. Ernie Fridge *NASA Johnson Space Center*
10:30	Break	
10:45	Intelligent Computer-Aided Training	Mr. Bowen Loftin *NASA Johnson Space Center*
11:15	Knowledge Based Systems Scheduler Re-Host	Ms. Lynne Cooper *NASA Jet Propulsion Laboratory*
11:45	Lunch	
1:00 - 3:00	PARALLEL SESSION: DISTRIBUTED SYSTEMS Session Chair: Mr. Gregory Swietek *NASA Headquarters*	
1:00	EMU System Evolution	Mr. Michael Rouen *NASA Johnson Space Center*
1:30	ECLSS Evolution Analysis	Mr. Sandy Montgomery *NASA Marshall Space Flight Center*
2:00	Environmental Control and Life Support System Automation	Mr. Brandon Dewberry *NASA Marshall Space Flight Center*
2:30	Environmental Control and Life Support System Predictive Monitoring	Dr. Richard Doyle *NASA Jet Propulsion Laboratory*
1:00 - 3:00	PARALLEL SESSION: TELEROBOTIC SYSTEMS Session Chair: Mr. Alan Fernquist *NASA Headquarters*	
1:00	Telerobotic System Technology	Mr. Wayne Zimmerman, Mr. Paul Backes *NASA Jet Propulsion Laboratory*
1:30	Telerobotics Ground Remote Operation	Mr. Wayne Zimmerman, Mr. Bruce Bon *NASA Jet Propulsion Laboratory*
2:00	Collision Avoidance Sensor Skin	Mr. John Vranish *NASA Goddard Space Flight Center*
2:30	Mars Aerobrake Assembly	Mr. John Garvey *McDonnell Douglas Space Systems Co. Advanced Product Development and Technology Division*

Space Station Freedom Status

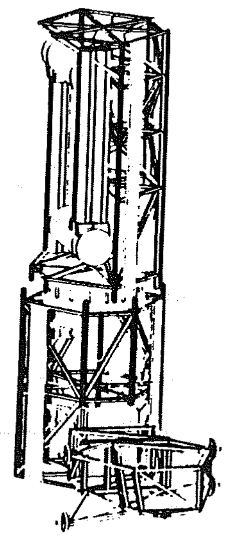


Space Station Evolution
Beyond the Baseline
August 6-8, 1991

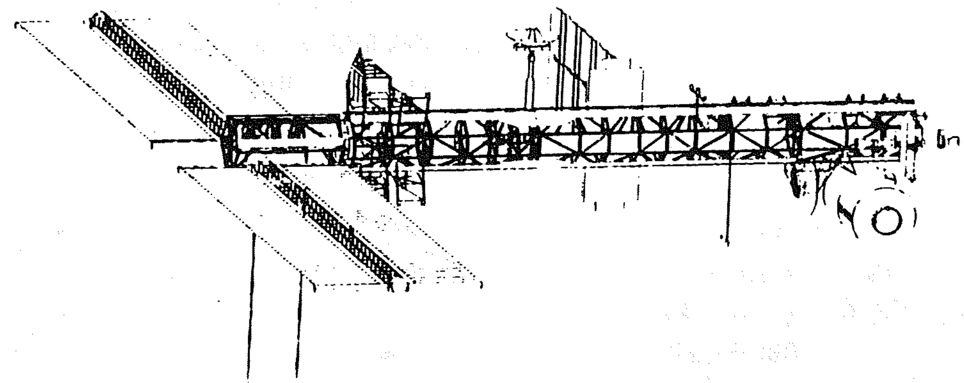
John Cox
Deputy Manager for Operations
Space Station Freedom Program & Operations



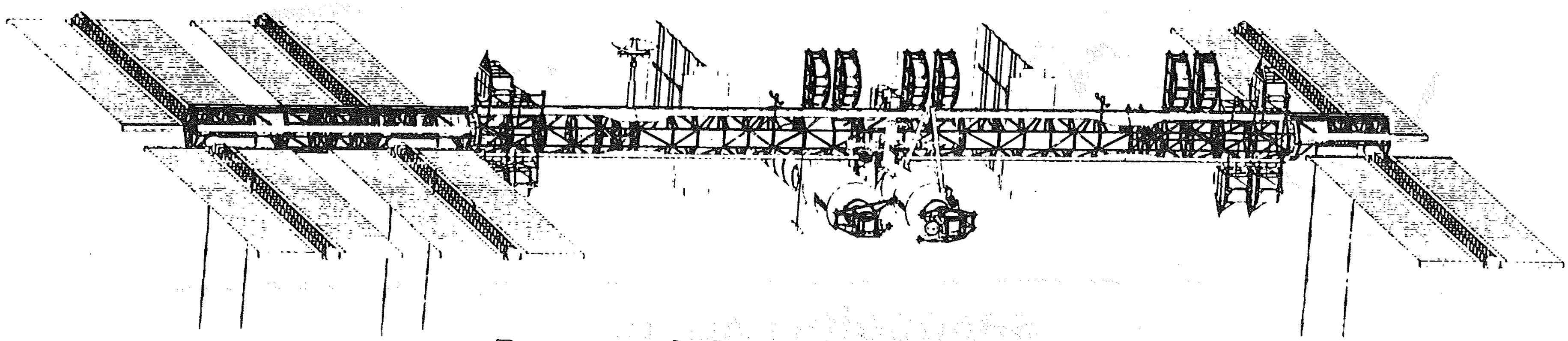
Space Station Freedom



First Element Launch (FEL)



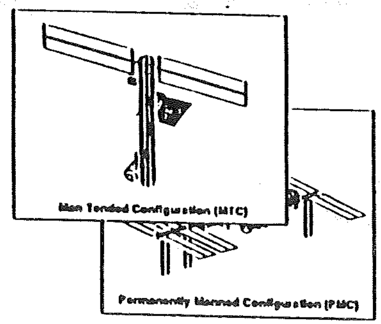
Man-tended Capability (MTC)



Permanently-Manned Capability (PMC)

Restructuring Integrates Many Objectives

RESTRUCTURED PROGRAM



NASA

- Provide Preeminent On-orbit Laboratory
  - 28 U.S. User Racks
  - 30 kW of Power
- Honor International Commitments
- Increase Ground Integration and Testing
- Simplify On-Orbit Assembly
- Reduce EVA
- Assure Crew Return
- Provide Flexibility for Changing Priorities and Budget Variations

CONGRESS

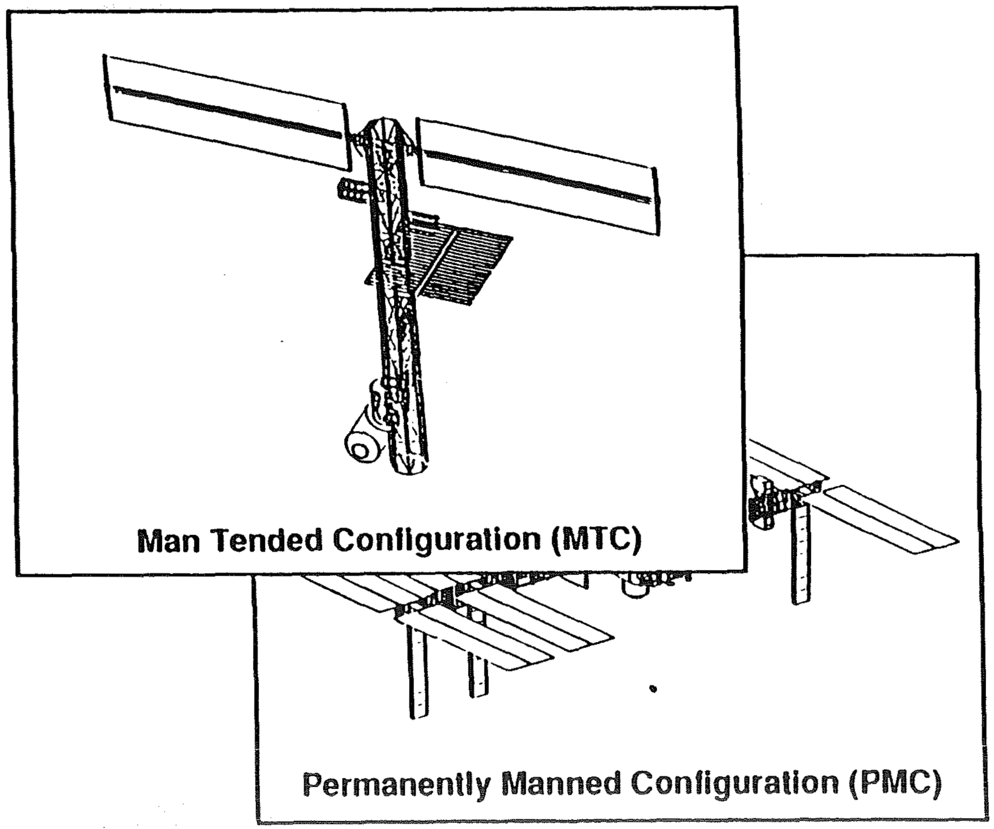
- Reduce Budget
- Provide Discrete Phases
- Emphasize Microgravity Sciences
- Achieve Early Man-Tended
- Utilization Flights During Man-Tended
- Adequate Power for U.S. Users
- Maintain International Committments

AUGUSTINE

- Accommodate Two Missions
  - Materials Science
  - Life Sciences
- Increase Ground Integration & Testing
- Reduce Transportation Requirements
- Reduce EVA
- Provide Crew Recovery Capability
- Reduce Size and Complexity

Restructured Space Station Freedom Program Meets Objectives

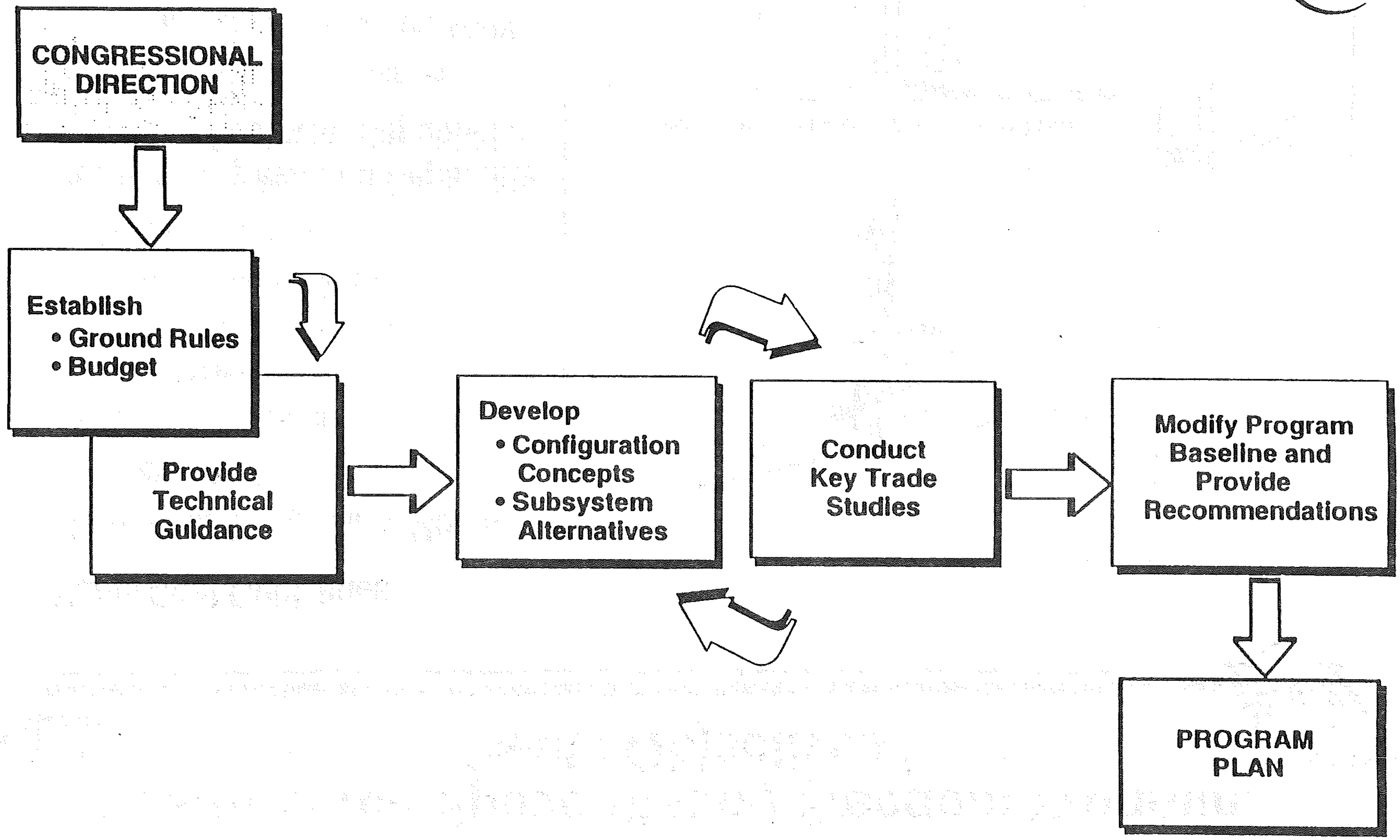
- **Meets Cost Guidelines**
- **Man-Tended Capability Meets All Objectives**
  - Microgravity Laboratory
    - 13 kW Users
    - 15 User Rack Locations
  - Reduced Size and Complexity
  - Simplified Assembly
- **Permanently Manned Capability Balances Cost with Capabilities**
  - Ability to Expand Life Sciences
  - Accommodates Crew of 4 and ACRV
  - Capability to Grow to Crew of 8, 75 kW Power



Man Tended Configuration (MTC)

Permanently Manned Configuration (PMC)

Restructuring Followed a Well-Integrated Process



Ground Rules Are Reflected In Program Themes

NASA
National Aeronautics and Space Administration

FREEDOM

GROUND RULES

- Budget
- Phased Approach
- Material/Life Sciences
- Early FEL; MTC
- Reduce Complexity & Transportation Requirements
- Honor International Commitments
- Build to PMC

RESTRUCTURING THEMES

- **Implement Program Management Directions**
  - Reduce Shuttle Flight Rate
  - Program Schedule Changes
- **Provide Design Simplification Guidelines**
  - Truss
  - Robotic Access
- **Preserve Design Flexibility**
  - Discrete Phases

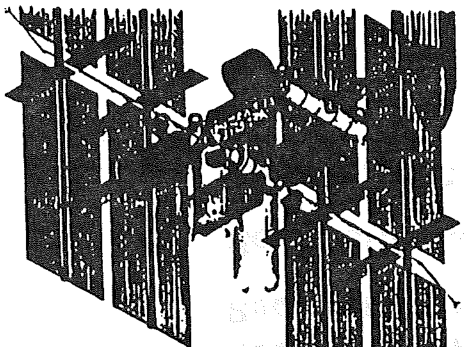
02/21/91 M/MM MS-9100123-114

Solution Adopted Best Features From Alternative Concepts

NASA
National Aeronautics and Space Administration

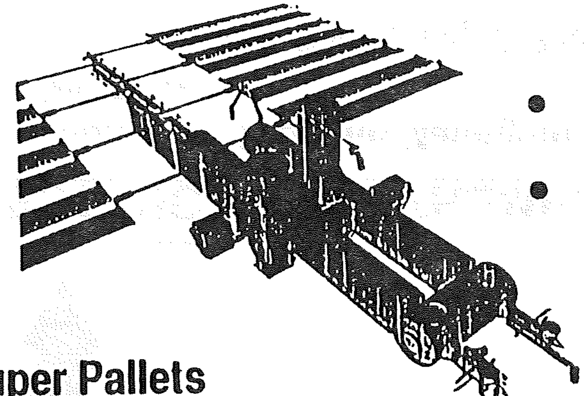
FREEDOM

Solar Inertial Station Concept (SISC) (Boeing)



- Ground Integration & Test
- Simplify Assembly

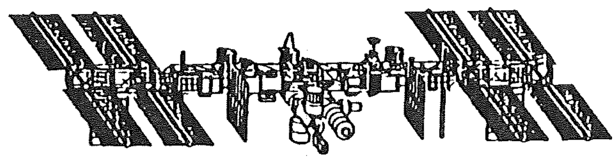
"Starship Enterprise"(JSC)



- Simplify Assembly
- Reduce Amount of External Hardware

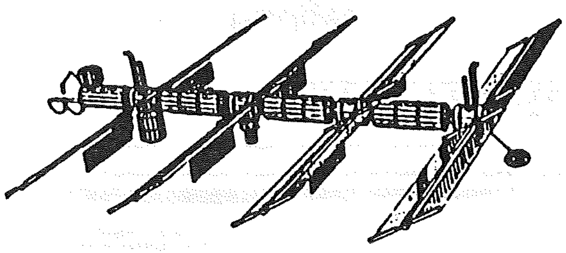
8

Ground Integrated Super Pallets (Grumman)



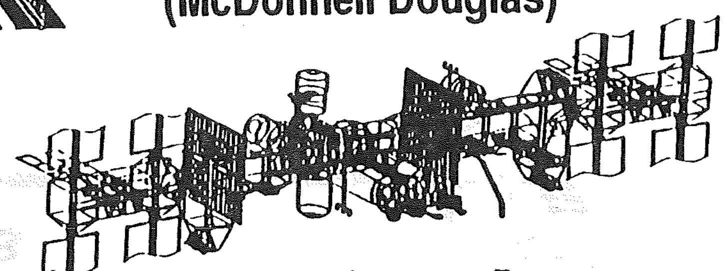
- Pre-Integrated Truss
- Short Lab/Hab

S.P.R.I.N.T. Concept (Martin Marrietta)



- Reduce amount of external hardware

ECAS (McDonnell Douglas)



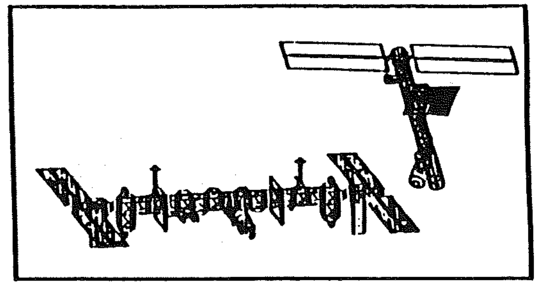
- Leverage Program Investment to date

Key Decisions Modify The Program Baseline

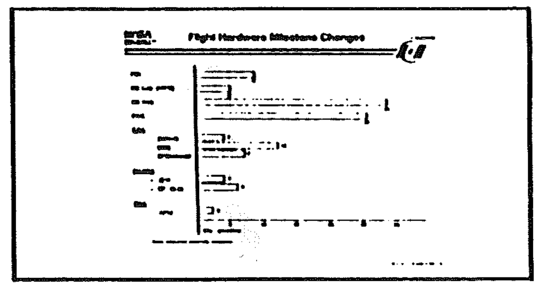
NASA
National Aeronautics and Space Administration

FREEDOM

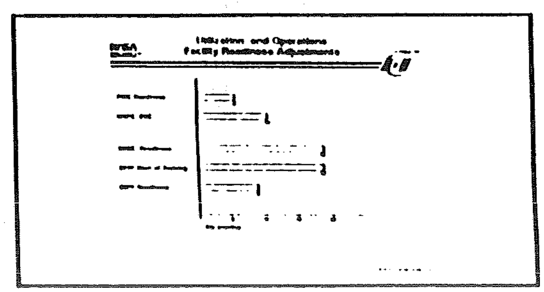
- **Selected 1/2 Boom Configuration for MTC**
  - Meets Microgravity Mission Requirements
  - Accelerates Lab Delivery



- **Deferred Key PMC Hardware Development**
  - Slipped Hab Module by 2 Years
  - Slipped PMC Accordingly
  - Relaxed Transportation Requirements



- **Phased Ground Capabilities Consistent With Flight Hardware**
  - Deferred Payload Operations Integration Center (POIC)
  - Deferred Space Station Outfitting
  - Reduced Processing Facility (SSPF) Footprints
  - Phased Space Station Control Center (SSCC)

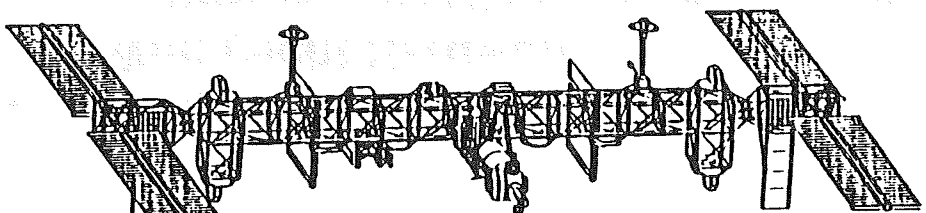


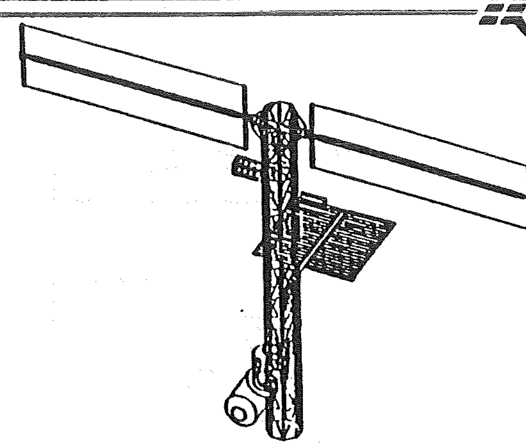
- **Simplified and Reduced Hardware Complexity**

NASA
National Aeronautics and Space Administration

Man-Tended Configuration Meets User Needs

FREEDOM





1990

- June 1996 (7 flights)
- Erectable Truss
- 2 Power Modules (25 kW User Power)
- 44' Microgravity Lab (24 User Racks)
- 1 APAE & FTS
- Mobile Transporter/Assembly Support Equipment
- 300 MB Communications Downlink

1991

- December 1996 (6 flights)
- Pre-Integrated Truss
- 1 Power Modules (13 kW User Power)
- 27' Microgravity Lab (15 User Racks)
- APAE deferred
- FTS transferred to OAET (Code R)
- Mobile Transporter Simplified
- 50 MB Communications Downlink
- On-orbit Integration Reduced

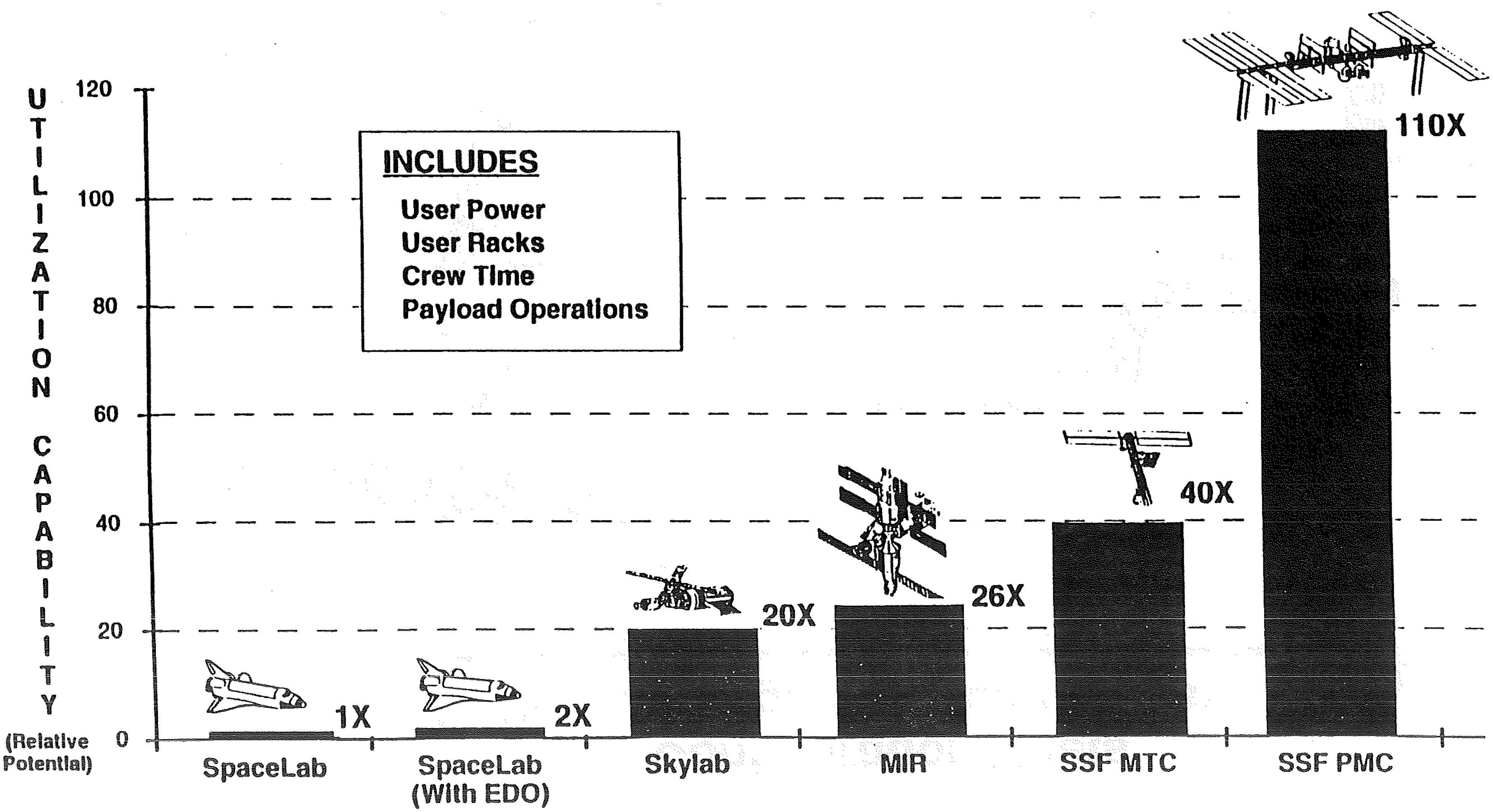
User Needs are Satisfied and Complexities Reduced

02/22/91 M/MM MSS 9100185 81a

NASA
National Aeronautics and
Space Administration

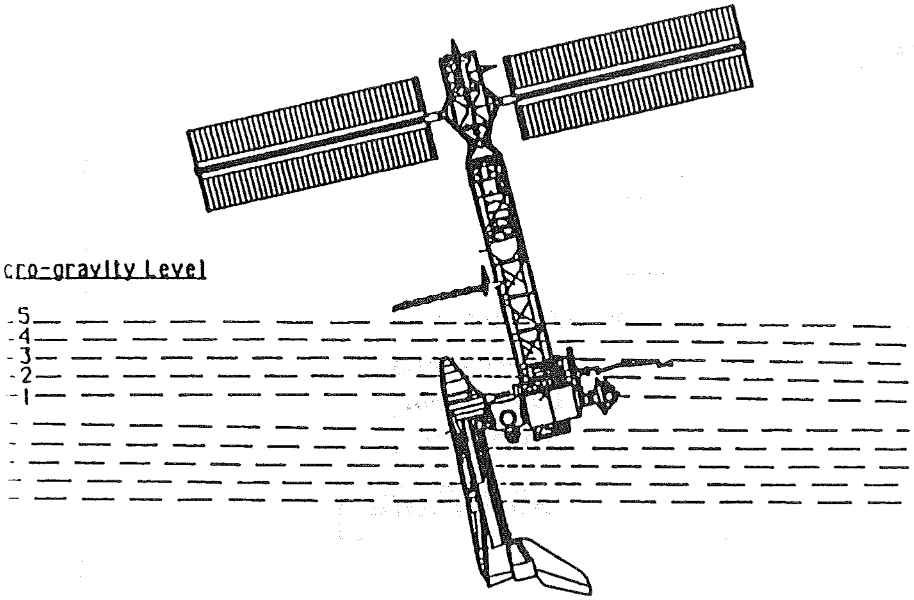
Space Station Freedom Allows Significantly Greater Utilization Opportunities Than Other Programs

FREEDOM

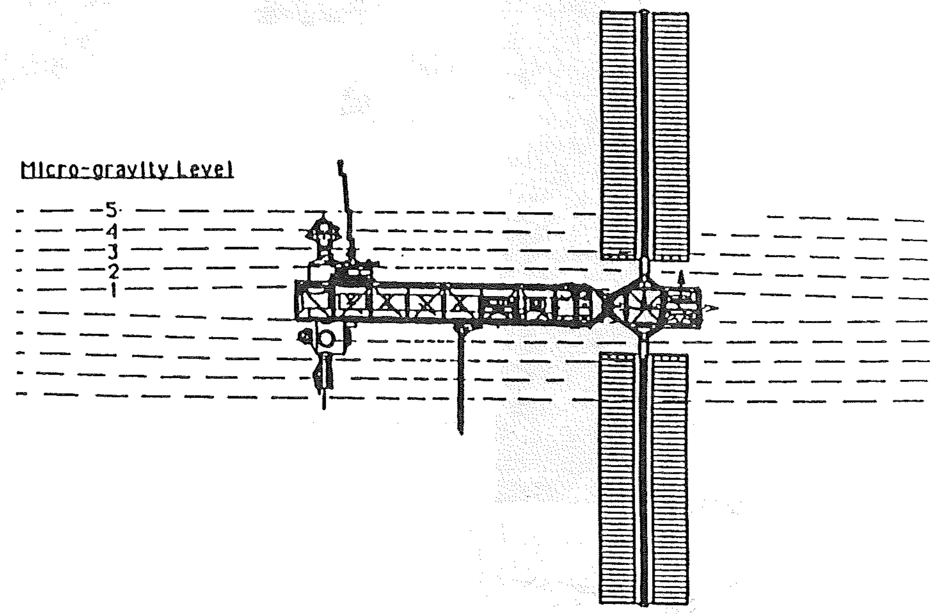


02/22/91 MJF MS 9100123 151c

MTC Configuration Meets US User Microgravity Requirements



Shuttle-Tended

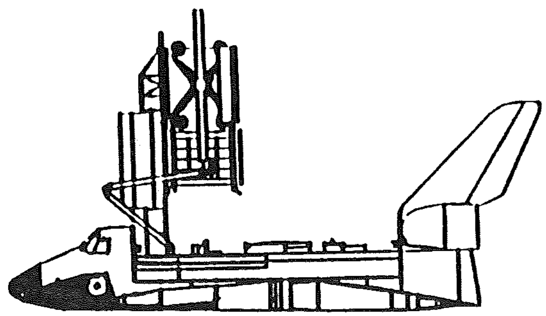
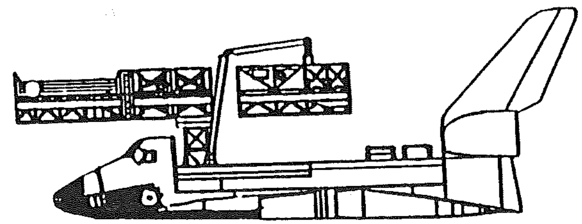


Free-Flyer

Microgravity Science Community Helped Drive Restructuring Changes

Pre-Integration Simplifies On-Orbit Assembly Planning and Operations

- Simplifies On-orbit Assembly Planning and Operations
- Reduces EVA Time 50%
- Eliminates Costly Training
- Maximizes Ground Testing and Verification

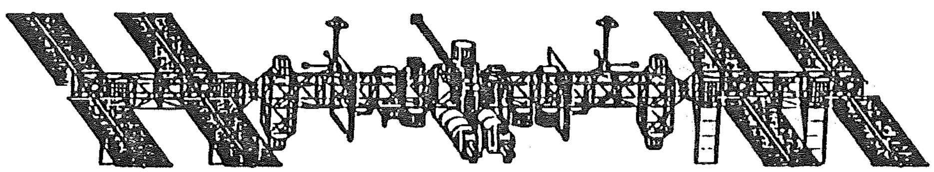
1990	1991
	
Erectable Truss Assembly (Beginning of MB-2)	Pre-Integrated Truss (Beginning of MB-2)

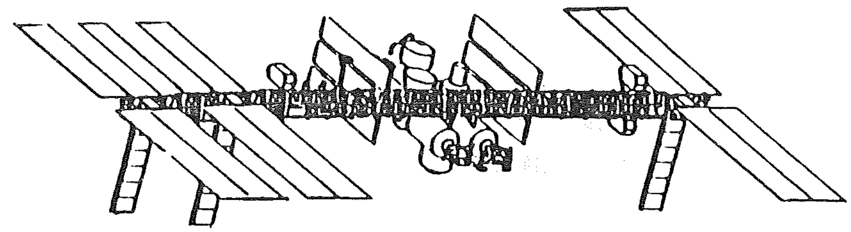
	1990	1991
• Assembly Elements to Manifest External Structure	128	20
• Assembly Elements to Outfit Module Pattern	69	13

NASA
National Aeronautics and Space Administration

Capability in 1999 Supports Life Sciences

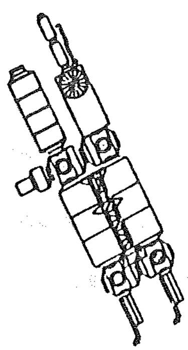
FREEDOM





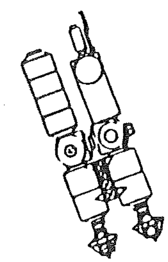
1990

- Assembly Complete Configuration
- 4 Power Modules (30 kW to User Power)
- 44' Lab Module (24 User Racks)
- 44' Hab Module (Crew of 8)
- Partner Modules (16 User Racks)
- 4 Nodes
- Closed Module Pattern
- 300 Mbps Downlink
- 20 Rack Logistics Module



1991

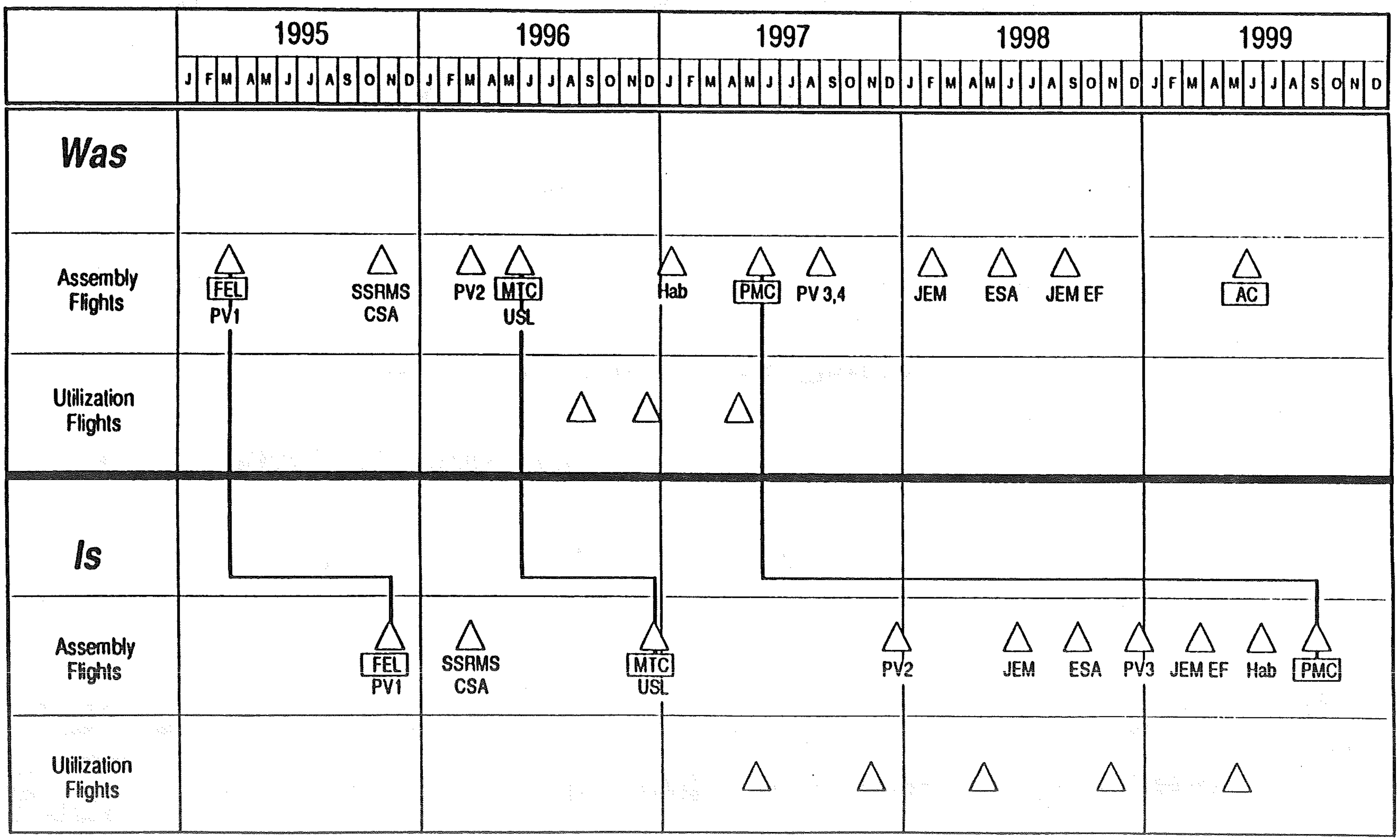
- Permanently Manned Configuration
- 3 Power Modules (30 kW to User Power)
- 27' Lab Module (12 User Racks)
- 27' Hab Module (Crew of 4)
- Partner Modules (16 User Racks)
- 2 Nodes
- Open Module Pattern
- 50 Mbps Downlink
- 20 Rack Logistics Module (Deferred)
  8 Rack Logistics Module
- Capability to Grow to Crew of 8, 75 kW
- Accommodates an ACRV



NASA
National Aeronautics and Space Administration

Program Milestones Phased to Meet Restructured Objectives

FREEDOM



Restructuring Activity Has Been a Success

- Balanced Program Meets Budget Through PMC
- Reduced Size and Complexity of Station
- Reduced Assembly Risk
- Minimized Impacts to International Partners
- Increased Ground Integration of Truss and Modules
- Increased Ground Based Test and Verification
- Reduced Demands on Transportation System
- Reduced On–Orbit Assembly and Checkout Requirements

THE NASA/Contractor Team is Behind the Restructured Program and Ready to Go

NASA
National Aeronautics and Space Administration

Space Station Freedom Program
Program Milestones

FREEDOM

CY90	CY91	CY92	CY93	CY94	CY95	CY96	CY97	CY98	CY99	CY00

- Program Preliminary Design Review, Dec 90
- MTC Phase Review, Oct 91
- SSFP Man-Tended Capability Phase - Critical Design Review (MTC/CDR), Mar 93
- SSFP Man-Tended Capability Phase - Design Certification Review, (MTC Phase DCR) Stages 1 and 2, Feb 95
- (MTC Phase DCR)Stage 3, June 95
- (MTC Phase DCR) Stage 4, Sept 95
- (MTC Phase DCR) Stages 5 & 6, Oct 95
- Operations Readiness Review (ORR), June 95
- First Flight Hardware Delivery (FFHD), July 95
- First Flight Readiness Review (FFRR), Sept 95
- First Element Launch (FEL), Nov 95
- Man Tended Capability (MTC), Dec 96
- JEM Module DDCU's & Heat Exchanger (ASRMs Required), June 98
- ESA Module, ESA DDCU's & Heat Exchanger (ASRMs Required), Sept 98
- JEM Exposed Facility, JEM ELM PS, JEM ELM ES (ASRMs Required), Mar 99
- Permanently Manned Capability (PMC), Sept 99

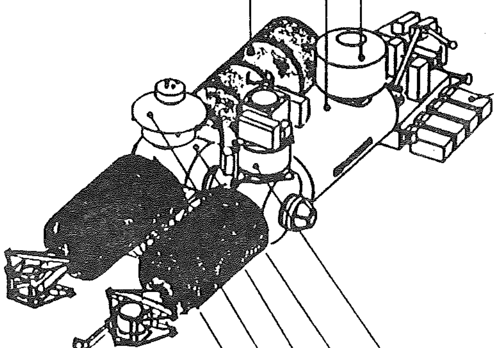
SSFPO 209
8/2/91

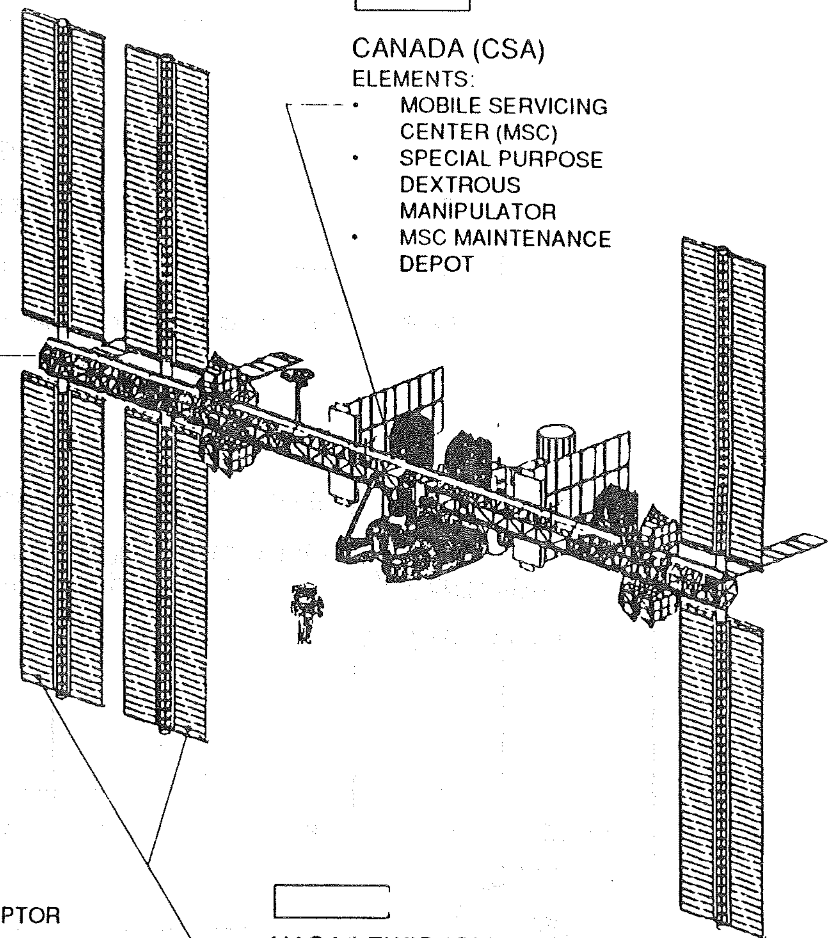
Station Freedom
Permanently Manned Configuration

EUROPEAN SPACE AGENCY (ESA)
ELEMENTS:
- PRESSURIZED LABORATORY MODULE
- MAN-TENDED FREE FLYER (MTFF)

JAPAN (NASDA)
ELEMENTS:
- PRESSURIZED LABORATORY MODULE & EXPOSED FACILITY
- EXPERIMENT LOGISTICS MODULE

CANADA (CSA)
ELEMENTS:
- MOBILE SERVICING CENTER (MSC)
- SPECIAL PURPOSE DEXTROUS MANIPULATOR
- MSC MAINTENANCE DEPOT





NASA/JOHNSON (Texas)
ELEMENTS:
- INTEGRATED TRUSS SEGMENTS BUILT AND CHECKED OUT ON GROUND
- MOBILE TRANSPORTER
- AIRLOCK
- INTEGRATED NODES
- SHUTTLE/SSF BERTHING DOCKING ADAPTOR

SYSTEM:
- EXTERNAL THERMAL CONTROL
- EVA SUPPORT EQUIPMENT
- DATA MANAGEMENT
- COMMUNICATIONS & TRACKING
- GUIDANCE, NAVIGATION & CONTROL
- PROPULSION
- ASSURED CREW RETURN VEHICLE

NASA/MARSHALL (Alabama)
ELEMENTS:
- PRESSURIZED SHELLS FOR NODES
- HABITATION MODULE
- LABORATORY MODULE
- LOGISTICS MODULES (PRESS & UNPRESS)

SYSTEM:
- ECLSS
- INTERNAL THERMAL CONTROL
- INTERNAL AUDIO & VIDEO
- MAN SYSTEMS EQUIPMENT

NASA/LEWIS (Ohio)
ELEMENTS:
- POWER MODULES - PV

SYSTEM:
- ELECTRICAL POWER SYSTEM

NASA
National Aeronautics and
Space Administration

Space Station Freedom: Reasons Why

FREEDOM

- Advance space science applications
- Explore the universe
- Preserve our planet
- Promote international cooperation
- Expand man's presence into the solar system
- Establish commercial opportunities
- Advance our nation's civil space program

The Logical Next Step

SSFPO 106
8/1/91

PRECEDING PAGE BLANK NOT FILMED

21

ESA Presentation for:
"SPACE STATION EVOLUTION:
BEYOND THE BASELINE"
Conference, League City, Tx 6/7/8 Aug.91

COLUMBUS PROGRAMME
(Current Status)

N92-17400

PAGE 20 INTENTIONALLY BLANK

D.C.Dell/ESA 8/91

COLUMBUS PROGRAMME (current status)

OUTLINE :

- FLASH BACK
- COLUMBUS PROGRAMME DESCRIPTION
- CLOUMBUS PROGRAMME RESTRUCTURING
- LATEST COLUMBUS PROGRAMME STATUS
- COLUMBUS PROGRAMME SCHEDULE

FLASH BACK :

- Europe responded to President Reagan's invitation in Jan.84 to participate in the "International Space Station Program" by proposing a three space element programme called "Columbus"
- Since the MOU with NASA on this programme was signed in September 1988, a number of changes were introduced due to NASA and ESA restructuring activities

COLUMBUS

COLUMBUS PROGRAMME (current status)

PROGRAMME DESCRIPTION:

- The Columbus Programme comprises a Space Segment, a Ground Segment, an Operations preparation Programme and a Utilization preparation Programme. A Columbus Exploitation Programme is expected to be initiated in the 1995/1996 time frame.
- The Space Segment consistes of three elements:
  - an Attached Pressurized Module (APM) – NSTS launched
  - a Man Tended Free Flyer (MTFF) – ARIANNE5 launched
  - a Polar Platform (PPF) – ARIANNE5 launched

COLUMBUS

COLUMBUS PROGRAMME (current status)

(Programme Description cont'):

- The Ground Segment is a programme shared with other European Programmes such as Hermes, for communications, services, training and tracking facilities, etc ...

- The Operations preparation Programme focuses on preparing the Ground Segment for readiness for the launch of the Space Segment Elements.

- The Utilization preparation Programme includes definition of candidate payload facilities, initial payload selection and precursor flights (Eureca, Spacelab).

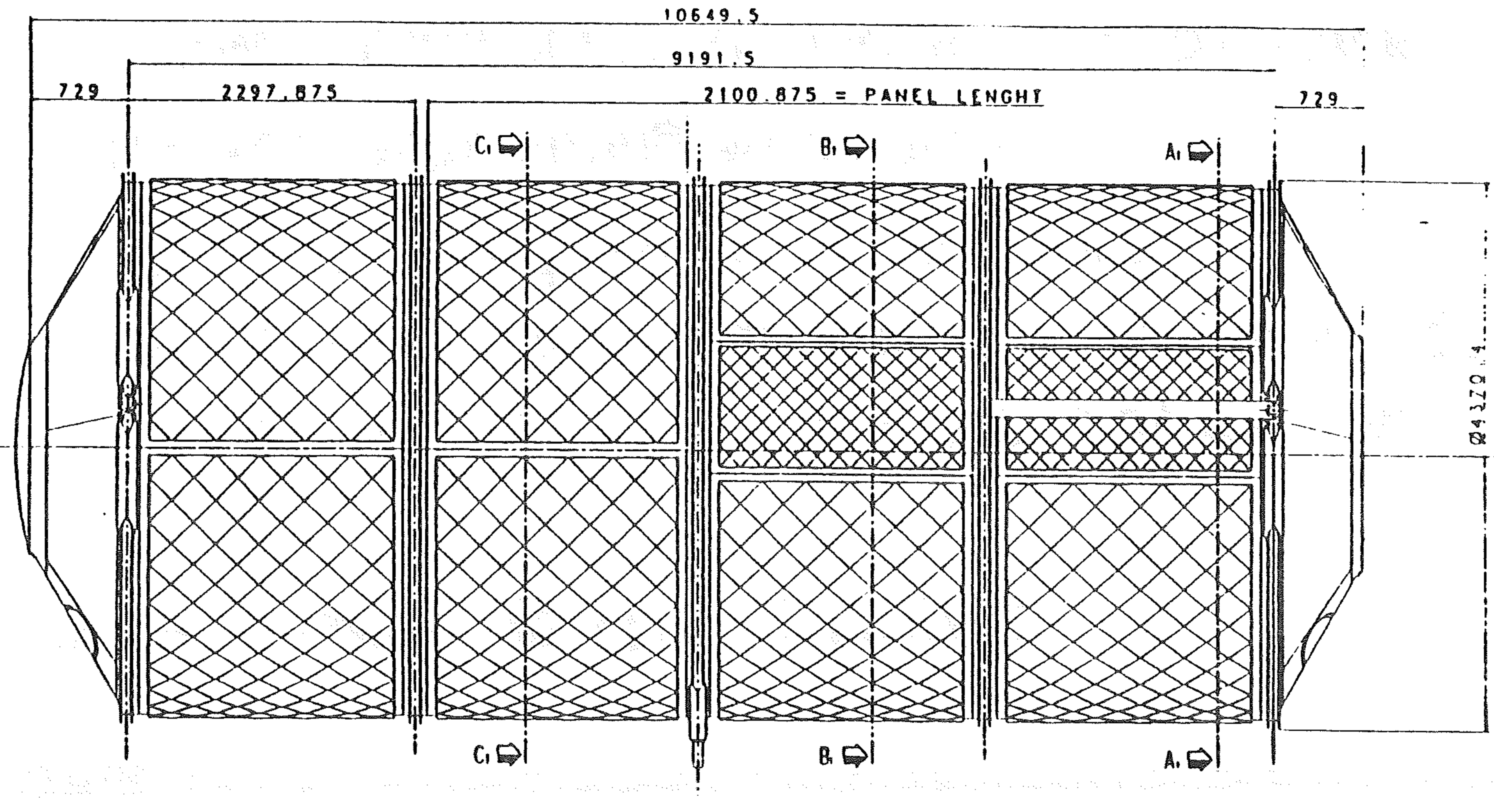
COLUMBUS

COLUMBUS PROGRAMME (current status)

PROGRAMME RESTRUCTURING:

- A Restructuring Phase was initiated by the NASA SSF restructuring activities as well as ESA internal schedule adjustments and cost reduction efforts.
- The key restructuring areas are:
  - Down sizing of the APM to an 8 Double Rack equivalent length, including subsystem simplifications. This is consistent with the NASA restructured baseline and schedule;

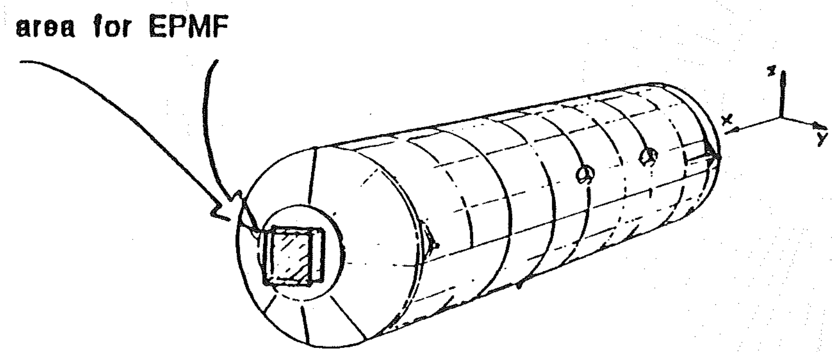
APM STRUCTURE CONFIGURATION



28

COLUMBUS PROGRAMME (current status)

EXPOSED PAYLOAD MOUNTING FACILITY
APM MASS & CoG IMPACTS

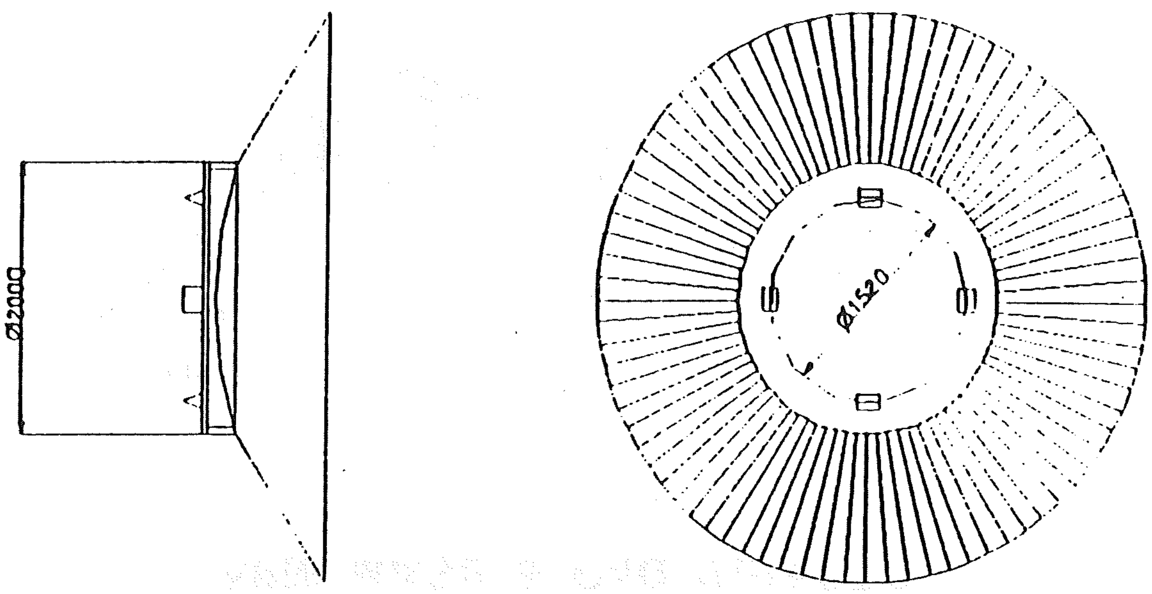


Assuming a Mass of 70 Kg for the EPMF, the variations of the APM Mass and CoG (4,000 Kg of Payload Included) are reported below:

- actual APM Mass = 17,351 Kg / 38,218 lbs (Instead of 17,274 Kg / 38,048 lbs)
- actual APM XCoG = 1,057.9 " (Instead of 1,059.0 ")
- global Mass (APM and other elements in NSTS cargo bay) = 19,982 Kg = 44,013 lbs
- global XCoG = 1,012.6 " XCoG - SRD = 17.2 "
- Manager Reserve = 3,287 lbs XCoG - SRD(with M.R.) = 11.6 "

EXTERNAL PAYLOAD MOUNTING FACILITY (EPMF)

EPMF LAY-OUT AND MAIN DIMENSIONS



COLUMBUS

COLUMBUS PROGRAMME (current status)

(Programme Restructuring cont'):

- The MTFF is no longer dependent on SSF for servicing, but Shuttle servicing is required for backing up the Hermes servicing. The launch date has been delayed to 2001/2002.
- The PPF was essentially not changed during the restructuring activities. Target launch date mid 1998.

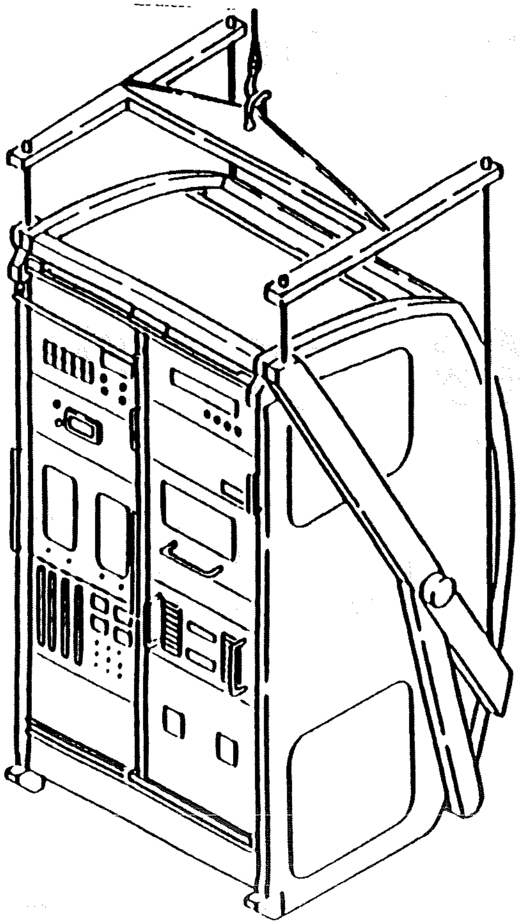
COLUMBUS

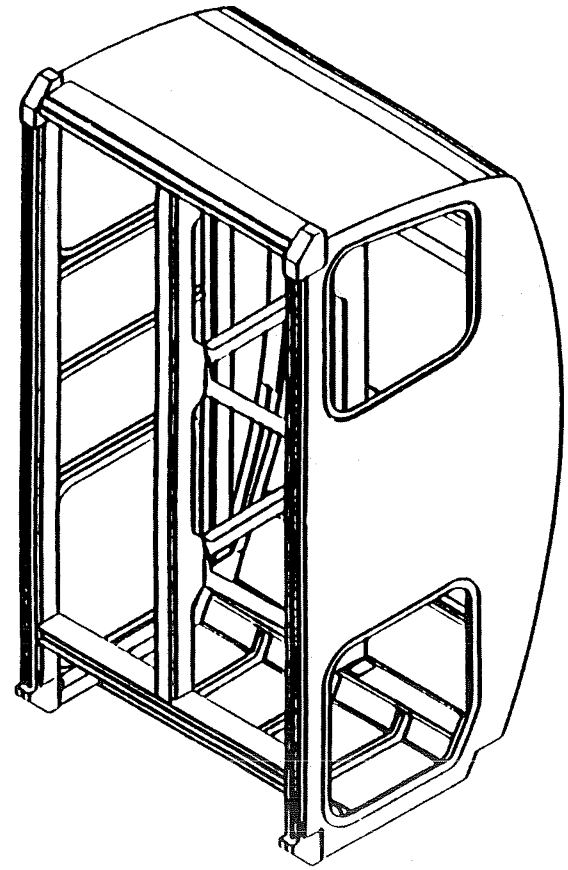
COLUMBUS PROGRAMME (current status)

LATEST PROGRAMME STATUS:

- TECHNICAL:
  - Achieved agreement with NASA and NASDA for experiment rack interchangeability (20 locations)
  - Agreement on essential APM to SSF interface requirements baselined at the SSCB

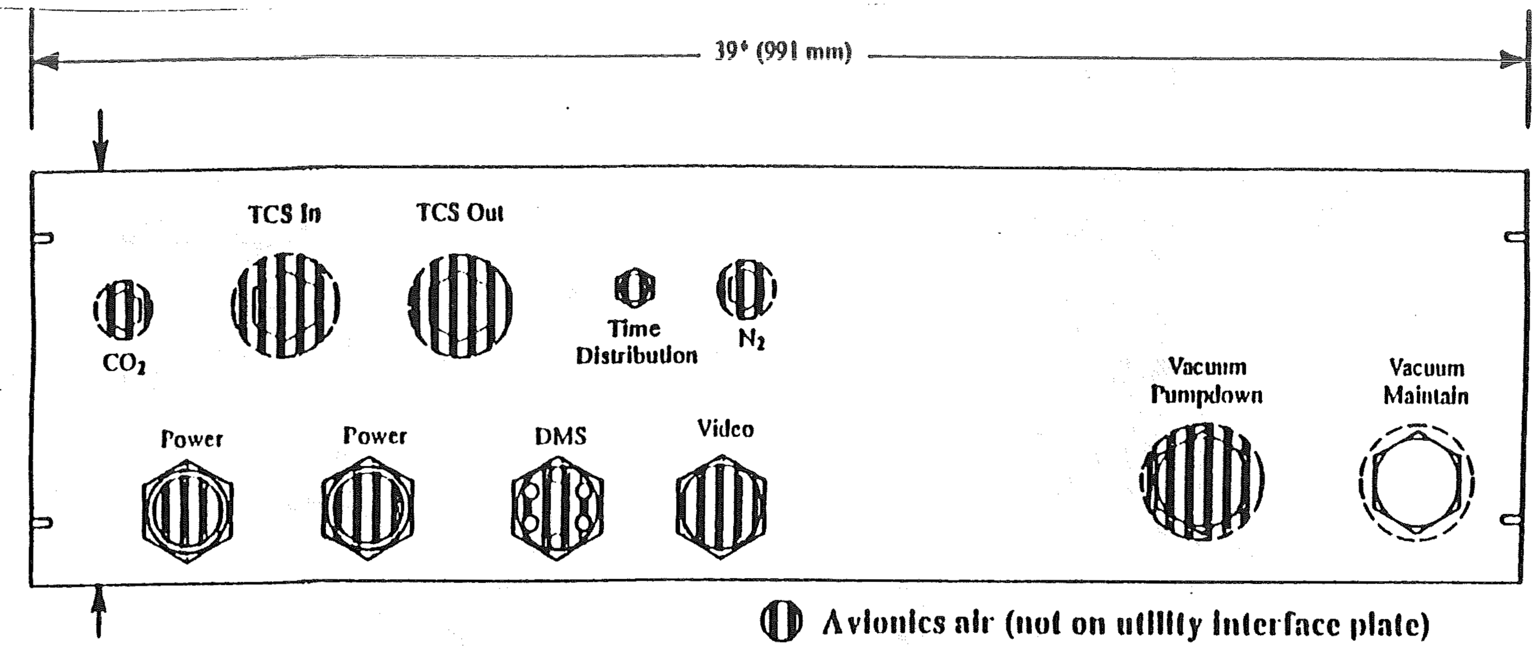
International Standard Payload Rack (ISPR):





Rack design includes common rack handling sling

COLUMBUS PROGRAMME (current status)



8.75"
(222)

Avionics air (not on utility interface plate)
Cabin air (not on utility interface plate)
Manual fire suppression (not on utility interface plate)

LEGEND		
▯▯	=	Payload basic set
TCS	=	Thermal Control System (Coolant Only)
UPWS	=	Ultrapure Water Service
DMS	=	Data Management System (High Rate Link & Local Payload Network Bus)

Standard Utility Connections

Every rack has standard utility connections

COLUMBUS

COLUMBUS PROGRAMME (current status)

(Latest Programme Status cont'):

- PROGRAMMATIC:
  - An Updated Industrial Commitment (UIC) received from European Industry which incorporates the restructuring changes as well as a significant cost reduction.
  - The APM and PPF baseline are firm, but further optimization of the MTFF baseline will be pursued, as the relaxed schedule can now easily accommodate this.

COLUMBUS

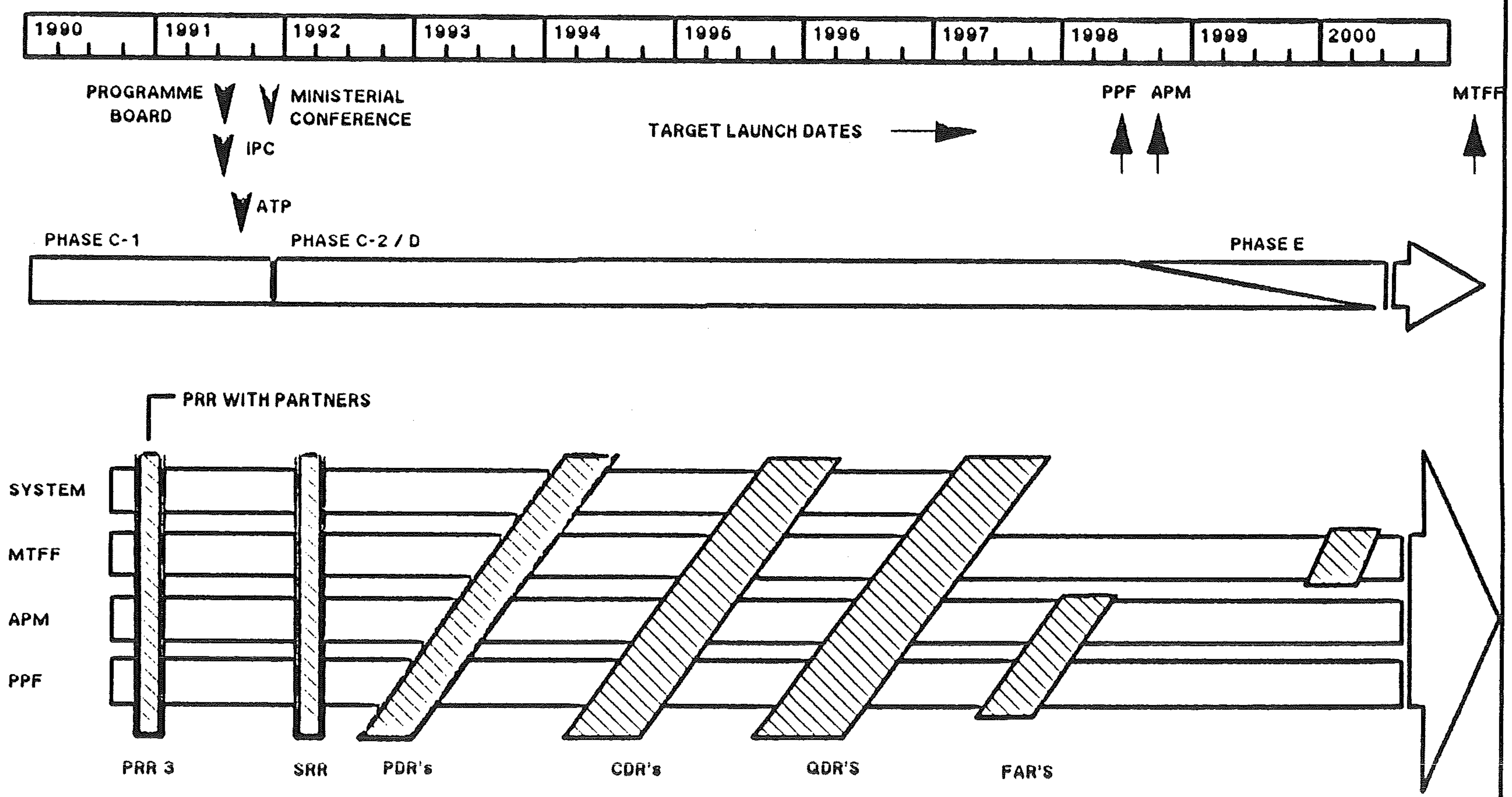
COLUMBUS PROGRAMME (current status)

CONCLUSION

- Current Columbus Programme status in line with NASA restructured Station (configuration and schedule)
- Current Columbus Programme status also in line with european intermediate and long term objectives
- Long term plan includes participation in SSF Programme, gradual evolution to autonomy in space and cooperation in future large scale space programs such as mission to the Moon or Mars, etc...

COLUMBUS SPACE SEGMENT - OVERALL PLANNING

STATUS: AUGUST 1991



(TOPSCHD11)
SSFO107/P

ESA - 6

NOTE: ALL PHASE C/D/E DATES PROVISIONAL

FREEDOM

Status of Japanese Experiment Module (JEM) Activities

Aug. 6, 1991

Houston, Texas

National Space Development Agency of Japan

(NASDA)

PRECEDING PAGE BLANK NOT FILMED

N92-17018

53-18

62384

NASDA

FREEDOM

HISTORY

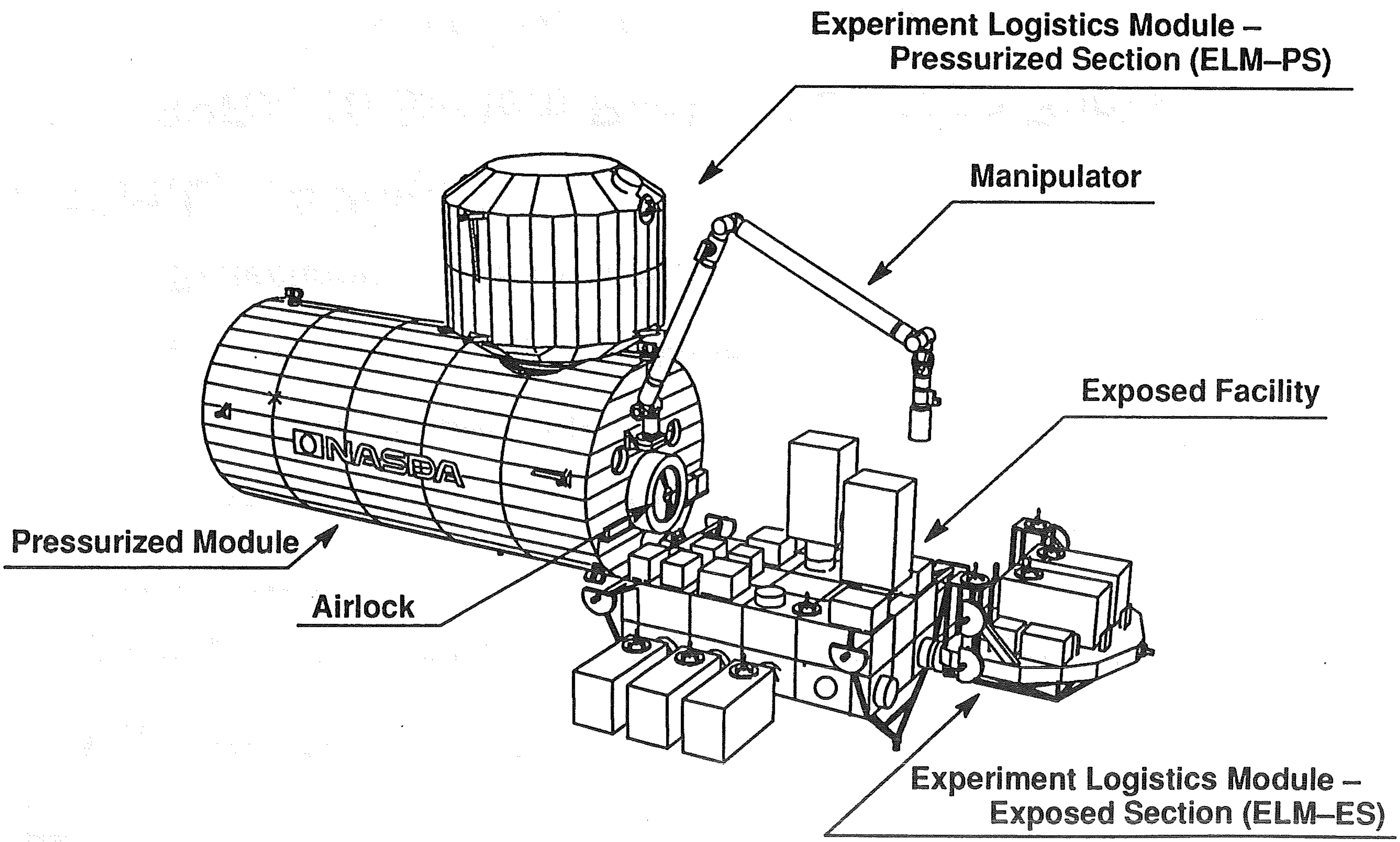
- 1984~ Conceptual Study, Basic Design
- March 1989 MOU Signed.
- Sep. 1989 Acceptance of IGA by the Japanese Diet.
- Jan. 1990 Approval to start JEM Program Preliminary Design received and Development Test for Elements started.
- Feb. 1991 Interim Design Reviews conducted.
- March 1991 Design of Engineering Model started.

NASDA

JEM CONFIGURATION

- Pressurized Module (PM)
- Exposed Facility (EF)
- Experiment Logistics Module
  - Pressurized Section (ELM–PS)
  - Exposed Section (ELM–ES)
- Remote Manipulator System (JEM RMS)

JEM Configuration



FREEDOM

PRESSURIZED MODULE (PM)

- Attached to the SS Node 2.
- Experiments conducted by crew in shirt–sleeve environment.

  Space Medical Experiments

  Biological Experiments

  Material Production Experiments

  Biotechnological Experiments
- 11m(L) × 4.2m(ID)
- 10 ISPRs, 10 System Racks, 3 Storage Racks
- Airlock at the Aft–end Cone 1.3m(D)

FREEDOM

EXPOSED FACILITY (EF)

- Open to Space Environment
- Facility for conducting

    Scientific Observation

    Earth Observation

    Experiments in Communications, Technology Development, and Material Science

- 5.3m(L) × 5.0m(W) × 3.7m(H)
- 10 Attached Payloads (Replaceable)

EXPERIMENT LOGISTICS MODULE (ELM)

– Pressurized Section (ELM–PS)

- Attached to the side port of PS.
- Provides functions such as storage and Transportation of Experiment Devices and Specimens as well as Mission Logistics
- 4.1m(L) × 4.2m(D), 8 Racks

– Exposed Section (ELM–ES)

- Attached to the tip of EF.
- Provides services such as Transportation of EF Payloads and ORUs.
- 1.8m(L) × 4.9m(W) × 3.6m(H)

FREEDOM

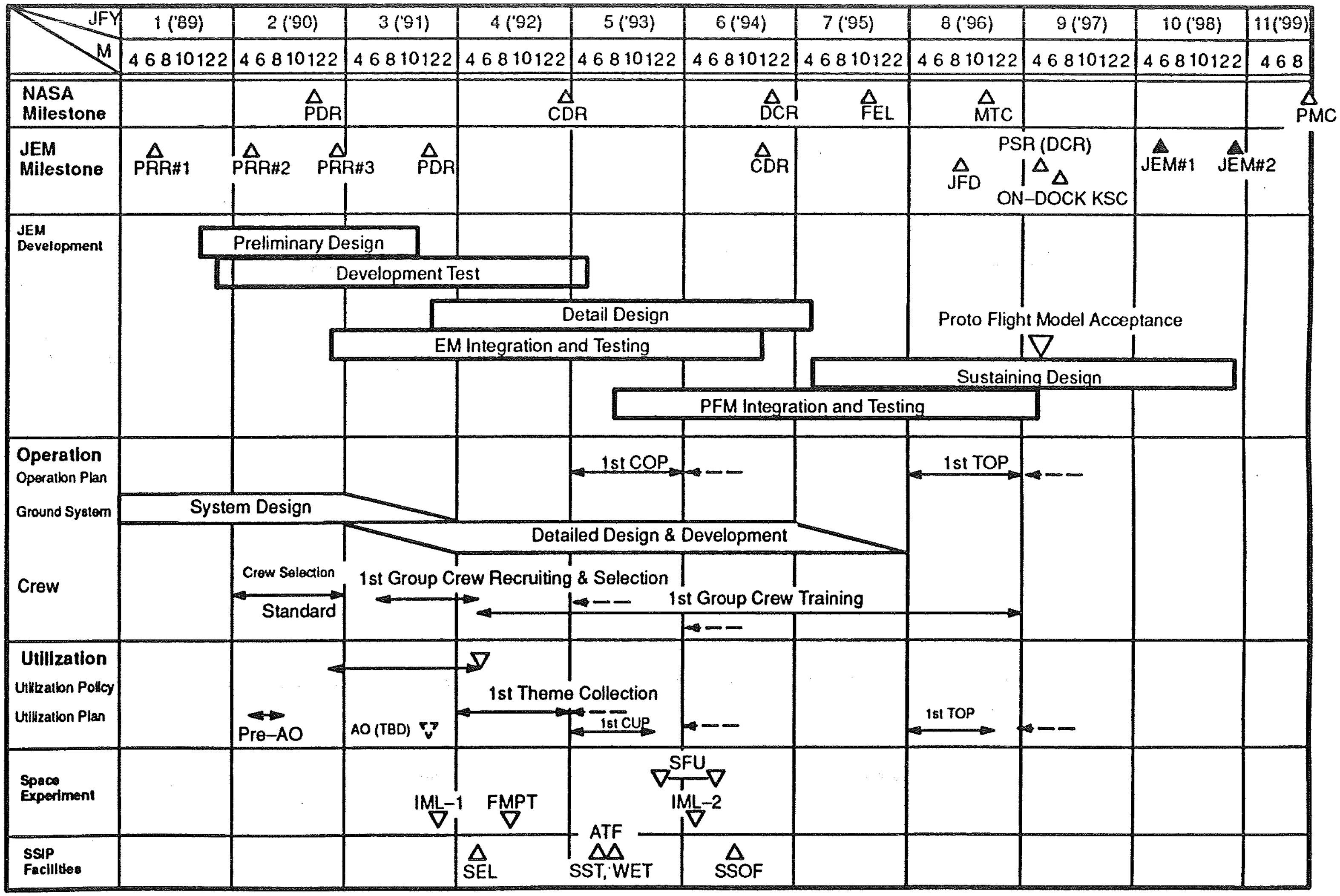
REMOTE MANIPULATOR SYSTEM (JEMRMS)

- Attached to the aft end Cone of PM.
- Operation Console located inside of PM.
- Composed of a Main Arm and a Small Fine Arm which is attached to the SEE of the Main Arm.
- Main Arm is 10m long, with maximum handling capability of 7000 Kg.
- Small Fine Arm is 1.8 m long and performs dextrous tasks.

FREEDOM

Space Station Master Schedule

(as of July 1991)



NASDA

FREEDOM

JEM DEVELOPMENT TEST

- Structure and Mechanism
- Electrical Power System
- Data Management System
- Thermal Control System
- Environment Control System
- Experiment Support System
- Remote Manipulator System

FREEDOM

SPACE STATION INTEGRATION & PROMOTION (SSIP) CENTER

– Purpose

- To conduct

  JEM development

  Operations, Training

  Planning and management

  Engineering support

– Configuration

- Located at Tsukuba Space Center

  Space Experiment Laboratory (SEL)

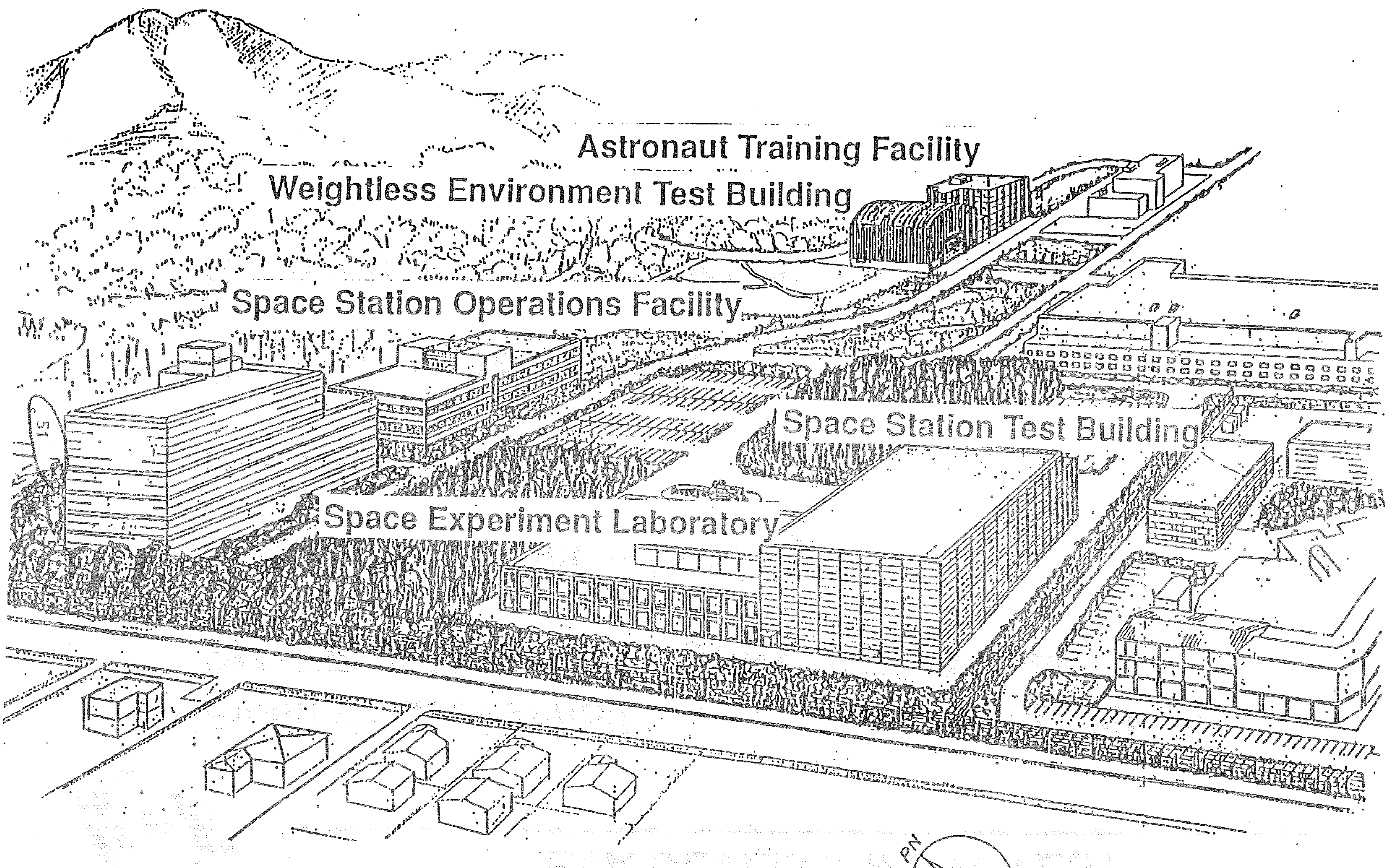
  Space Station Test Building (SST)

  Astronaut Training Facility (ATF)

  Weightless Environment Test Building (WET)

  Space Station Operations Facility (SSOF)

NASDA



pace Station Integration & Promotion (SSIP) Center

FREEDOM

EVA DEVELOPMENT TEST

- Evaluate accessability to and maintainability of PM, EF, JEMRMS and OURs by EVA Crew.
- Scheduled Oct. – Nov. 1991
- Use NBS in MSFC
- Mock–up is being designed.
- Reflect in the current design.

FREEDOM

JEM DATA RELAY VIA COMETS

- Provide JEM–to–Ground data link

  50 Mbps data rate through Ka–band.

  Up link not planned to JEM.

- Equipment installation including antenna on JEM–EF as an experiment payload.

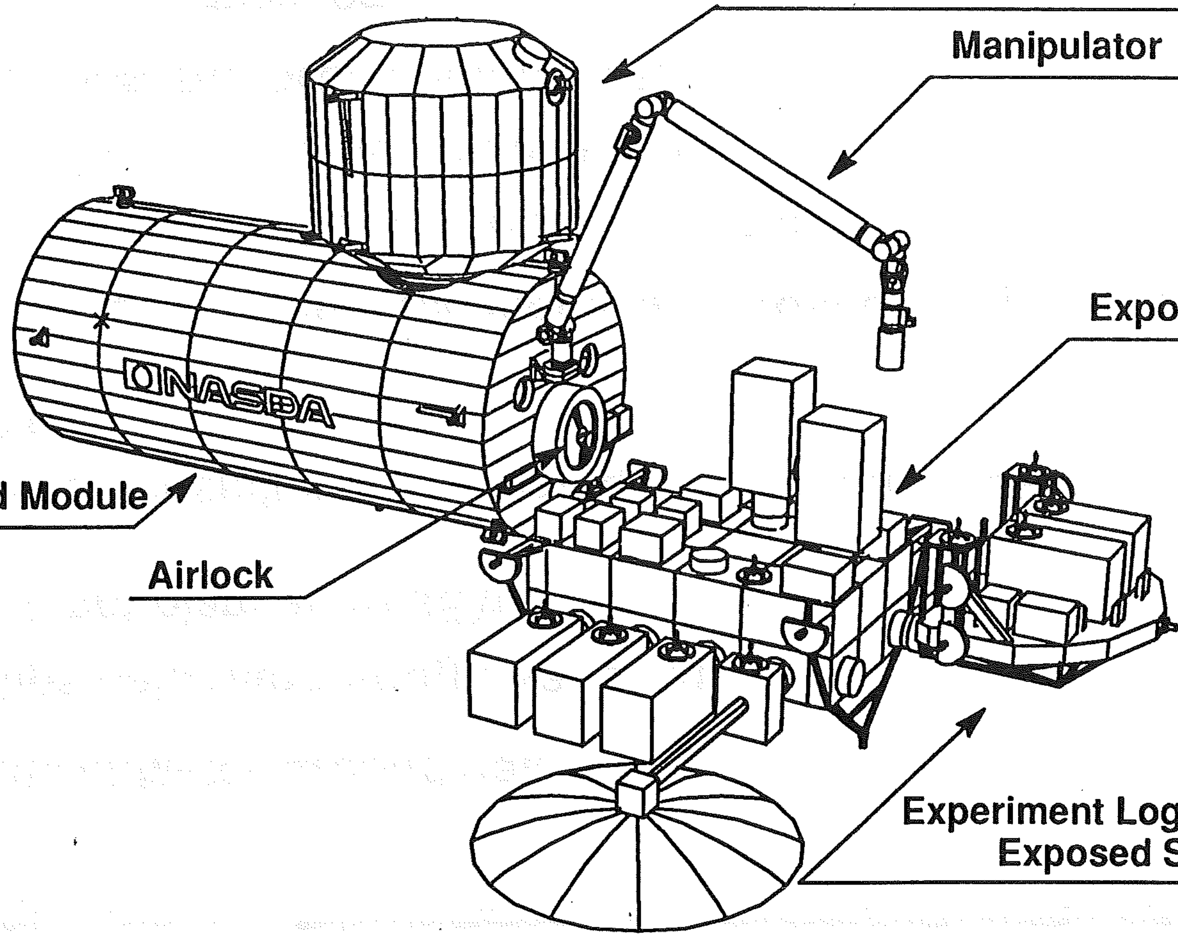
- Use COMETS (Communications and Broadcasting Test Satellite)
  - Multifrequency Band integration technology
  - Scheduled to be launched in 1997.
  - Missions:Interorbit communications

    Advanced mobile satellite communications

    Advanced satellite broadcasting

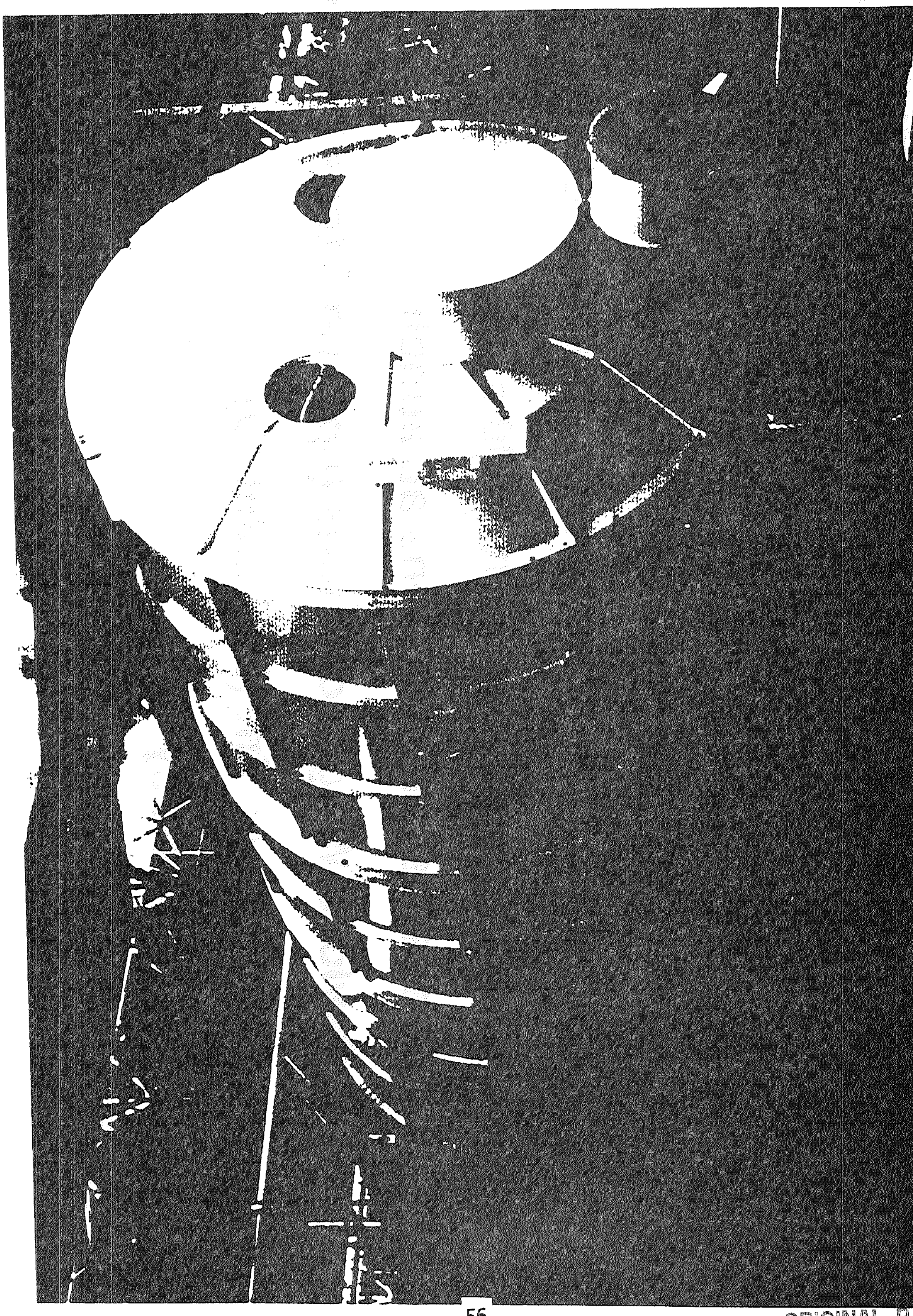
NASDA

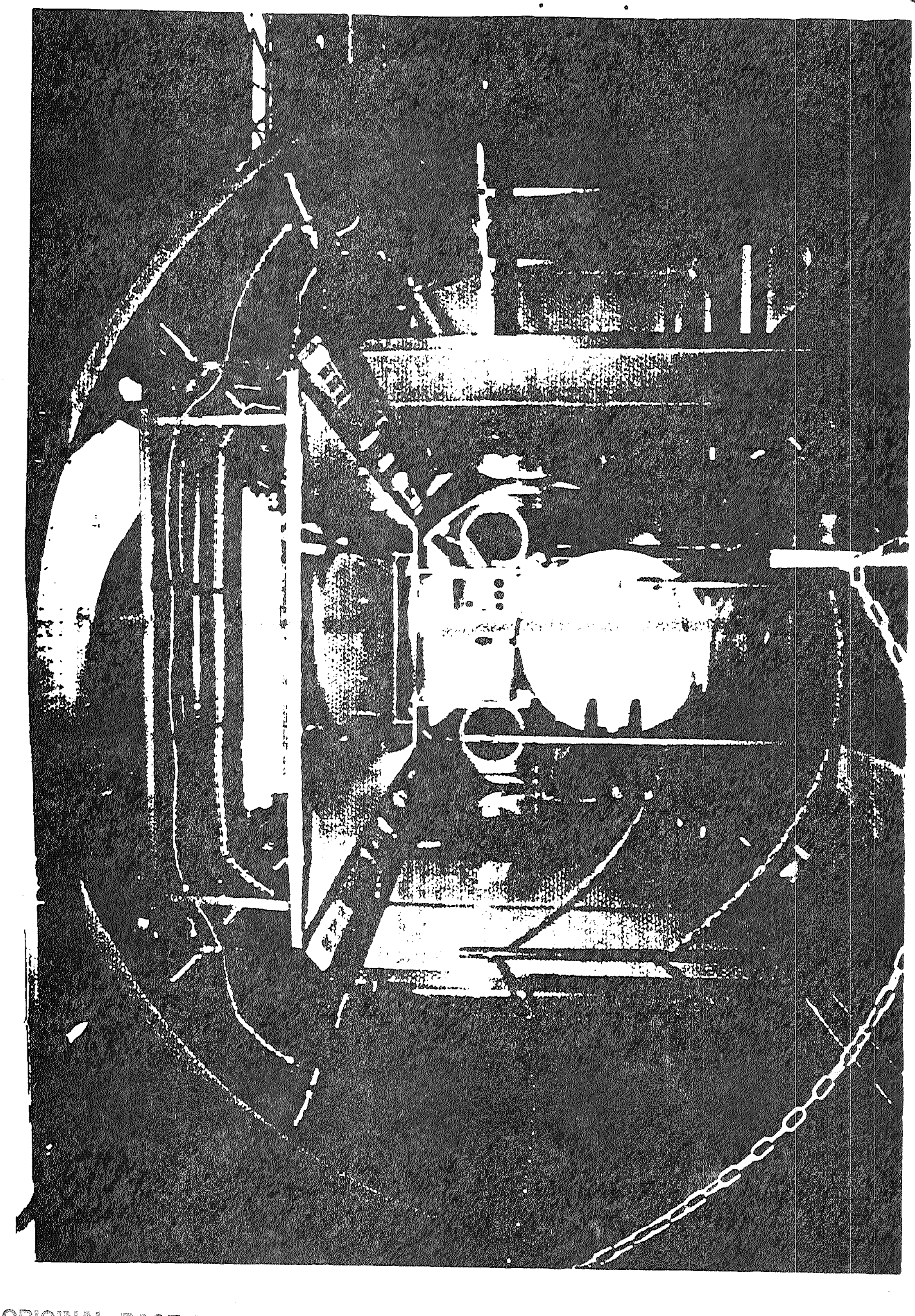
JEM Configuration–1

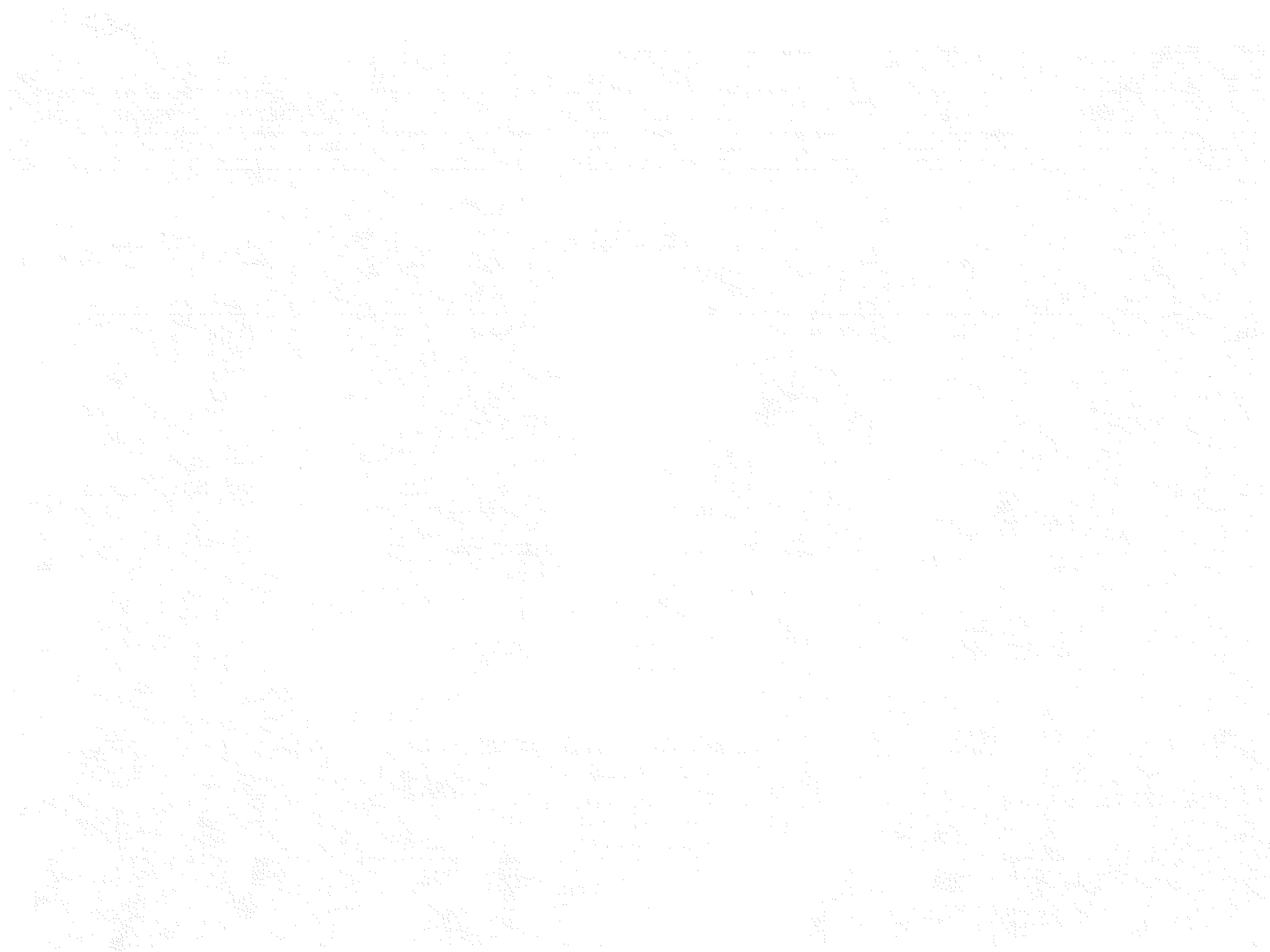


H–II ORBITING PLANE (HOPE)

- To carry cargo to / from Space Station / JEM
- Launched by H–II or H–II derivative Vehicle
- Unmanned, fully automatic and reusable
- Operational in the early 2000's
- Gross weight of 20 tons at launch
- Payload Weight of 3 tons (up) and 5 tons (down)
- Cargo bay : 6m (L) × 2.8m (D)
- Phase A study







Canadian Space Station Program

K.H. Doetsch
Director General
Canadian Space Station Program

August 6, 1991
League City, Texas

Mobile Servicing System
Système d'entretien mobile

Canadian Space Agency
Agence spatiale canadienne

The Canadian Space Station Program

- Mobile Servicing System
  - Development, use and operation
- Strategic Development
  - Space station utilization and operations
  - Evolution
  - Technology development
  - User development
  - Industrial development

Canadian Space Agency   Agence spatiale canadienne

SSPO-KHD Aug 6/91

Mobile Servicing System

- Canada's contribution provides essential facility for assembly, maintenance and servicing of Space Station
- Required to support several phases:
  - assembly
  - initial operations
  - mature operations
  - evolution

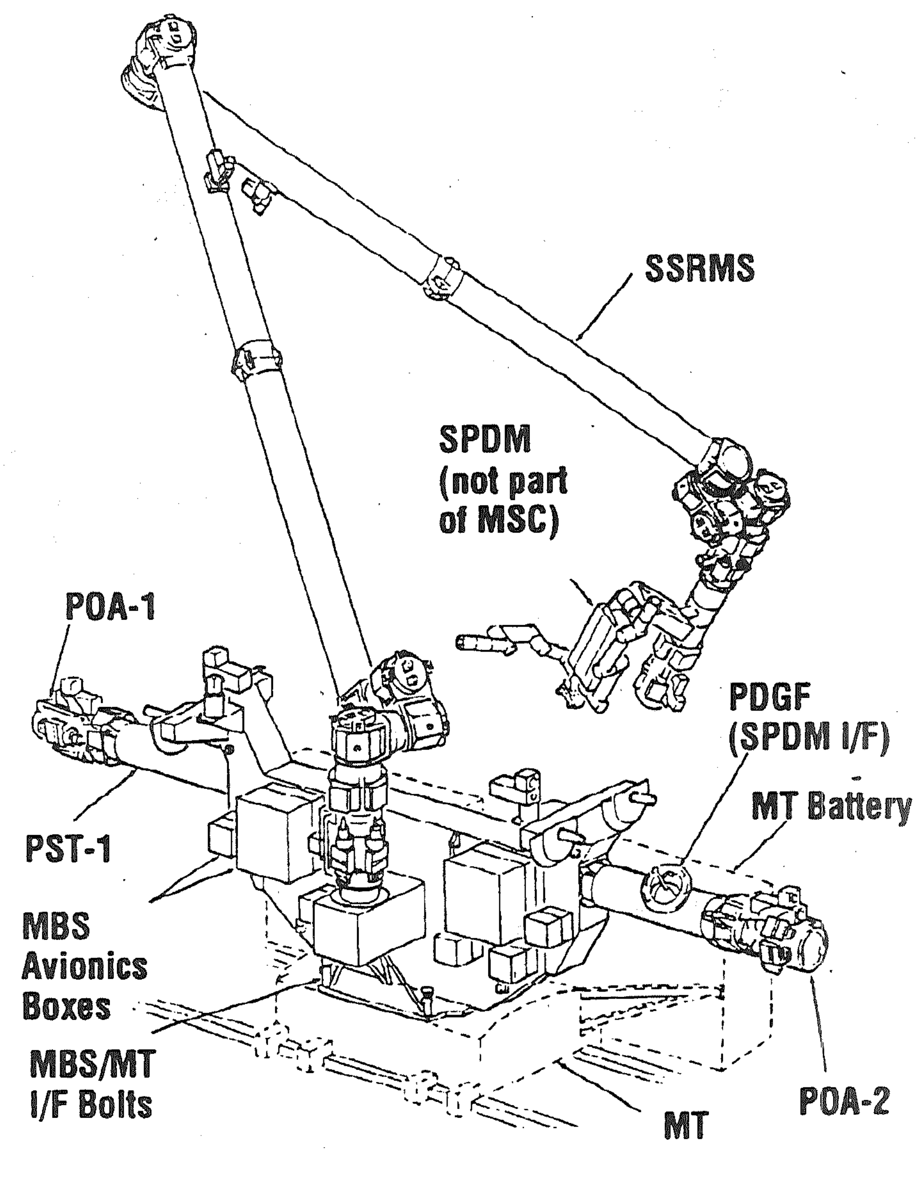
Major impacts of restructuring on Canadian Program

- MSC delivery to orbit phased, MB 3 and MB 6
- MT operates only along one face of truss
  - Routine orbiter/station logistics tasks no longer possible from MT as base
  - Direct operations viewing by operator impeded
- MSC control from aft node and STS

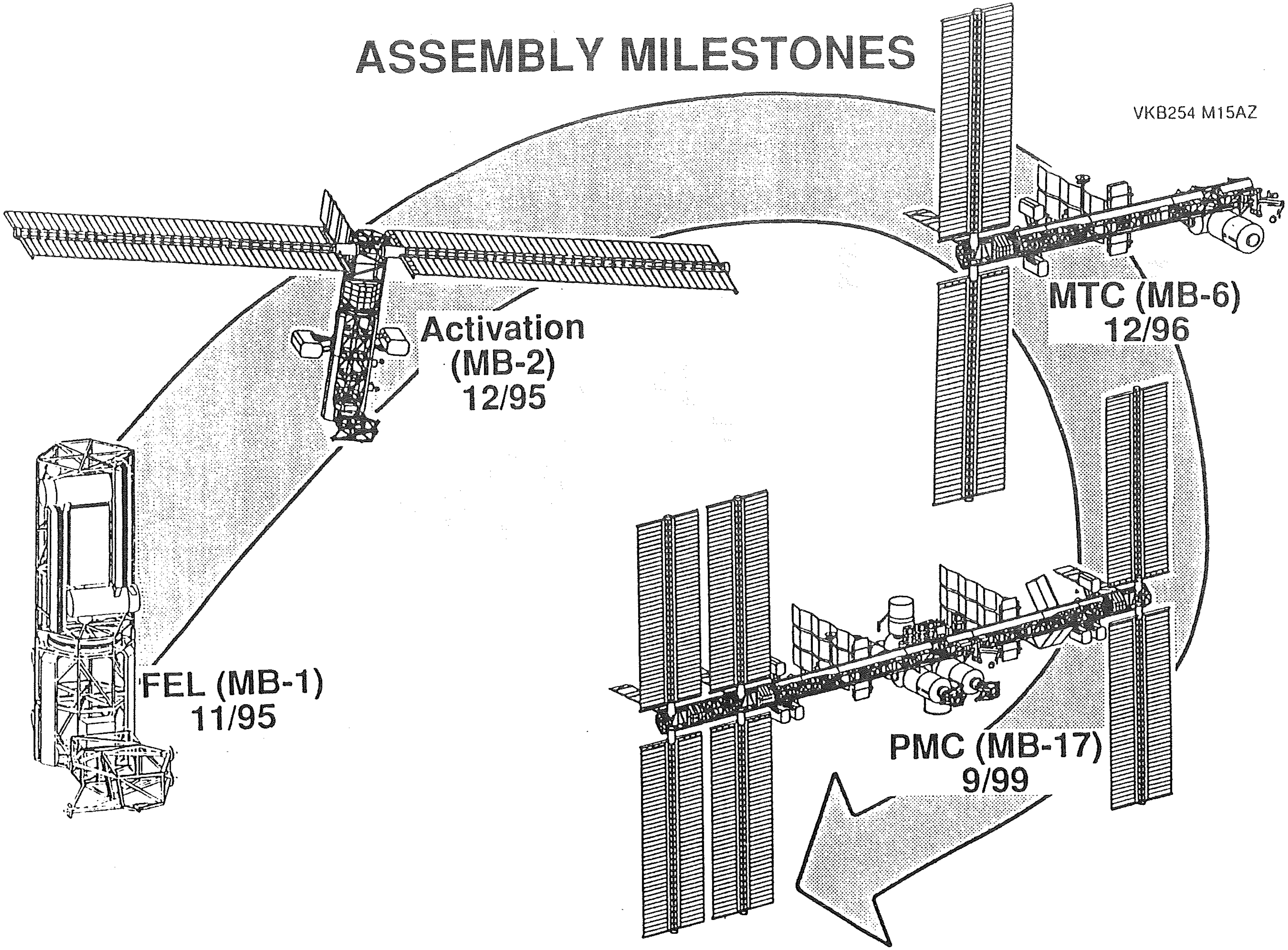
Assembly Sequence Launch Manifest

Date	Flight		Assembly elements
11/95	1 FEL	MB-1	Truss section (S3/4) with stbd indb PV system, alpha joint, propulsion module platforms, passive dampers, MT, unpressurized berthing adapter
12/95	2	MB-2	Truss section (S2) with CMGs, C&T (S-band), two propulsion modules, S-2 avionics
3/96	3	MB-3	Truss section (S1) with stbd TCS, UHF and KU-band antennas, SSRMs
6/96	4	MB-4	Truss section (M1) with IUD, MTS, GCS , cryo berthing mechanisms (2), node 1&2 umbilicals, CETA cart (2), MT batteries
9/96	5	MB-5	Aft port node, Pressurized Docking Adapter (PDA), cupola
12/96	6 MTC	MB-6	U.S. lab module core - A, system racks, 4 user payload racks, MBS (ASRMs required)
3/97	7	MB-7	Airlock, pressurized docking adapter, SPDM/MMD
5/97		UF-1	Mini PLM, Cryo O2/N2
6/97	8	MB-8	Truss section (P1) with port TCS, C&T (UHF ant.)
9/97	9	MB-9	Truss section (P2) with dry cargo berthing mechanisms (3), 2 propulsion modules

Mobile Servicing Centre

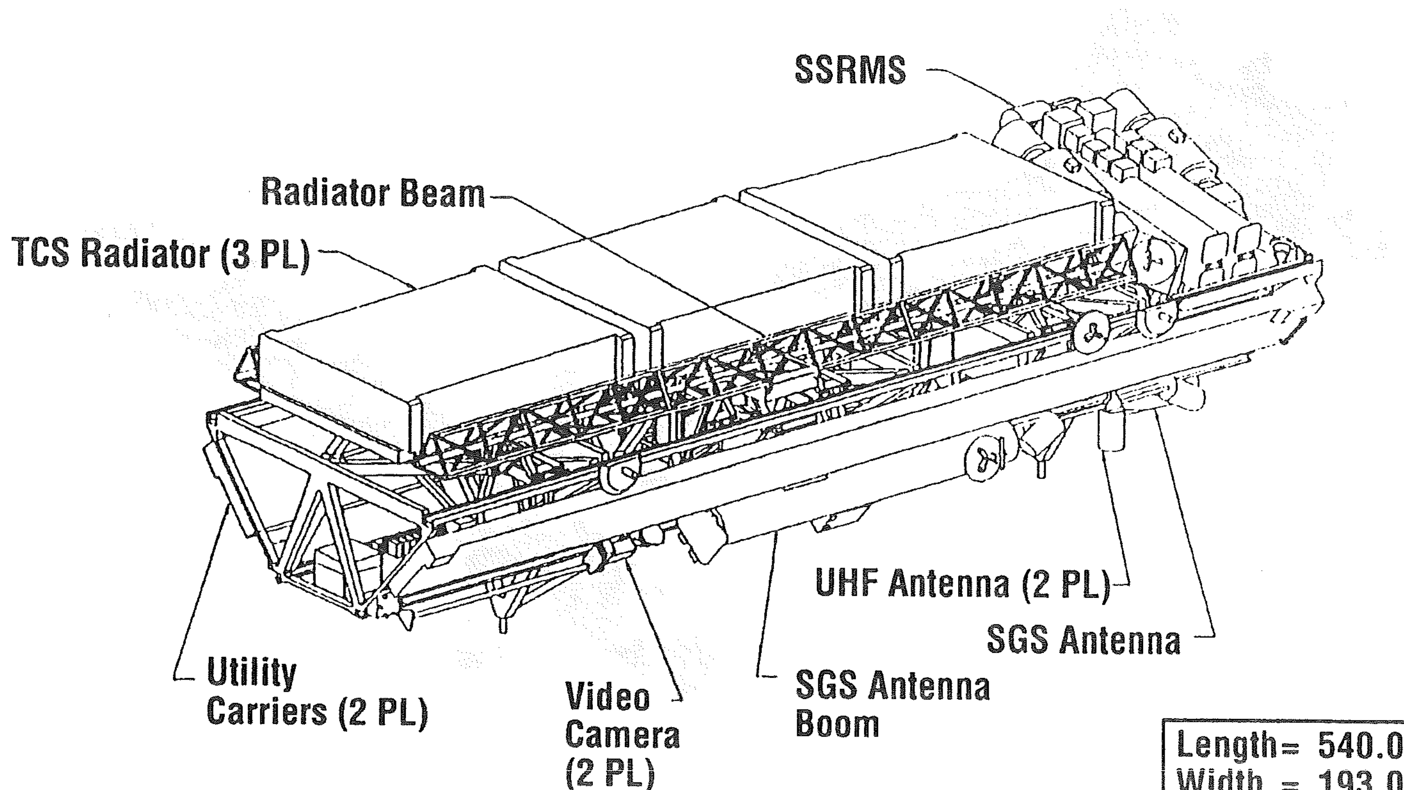


ASSEMBLY MILESTONES



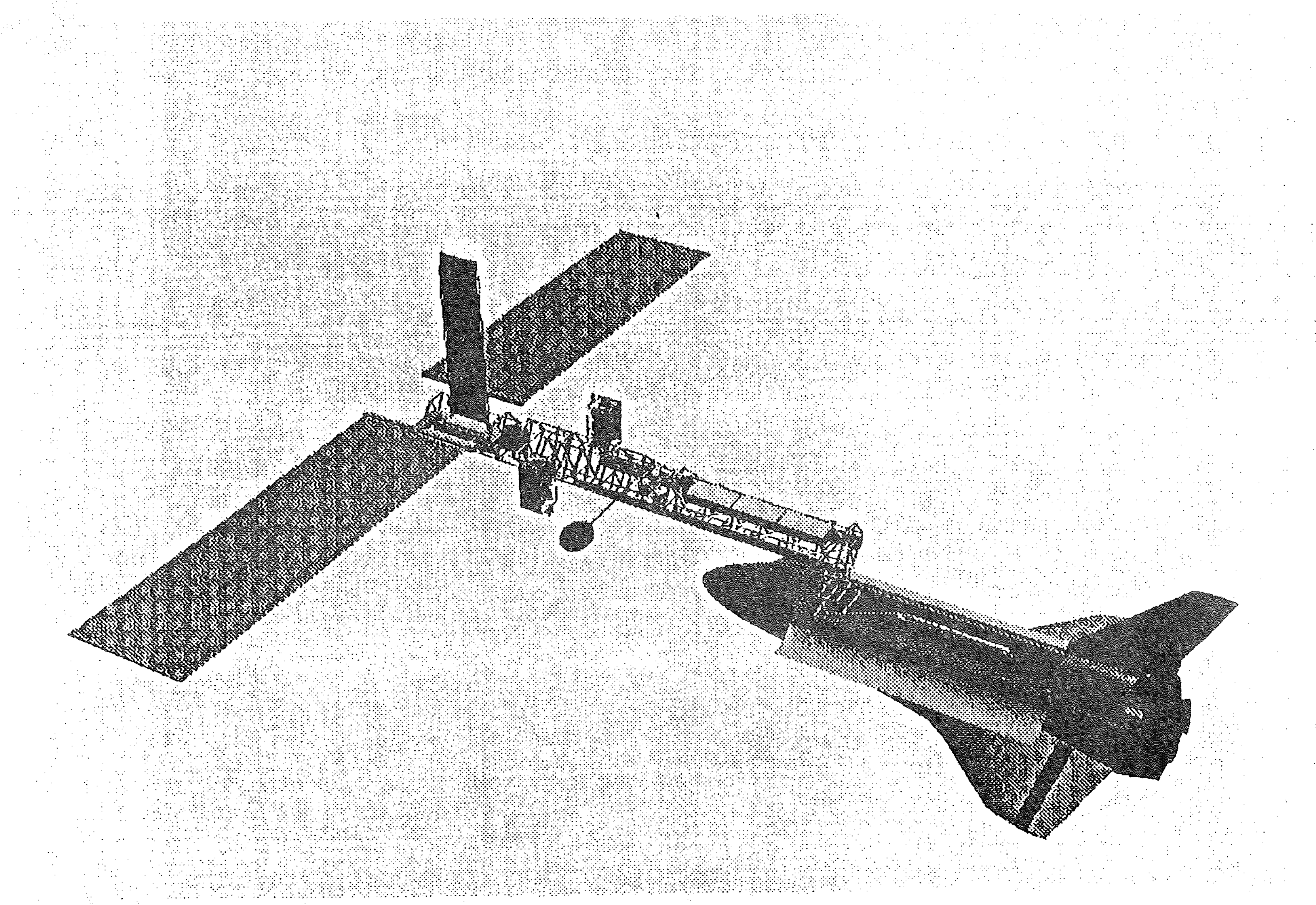
—Space Station Freedom

MB-3 Launch Configuration



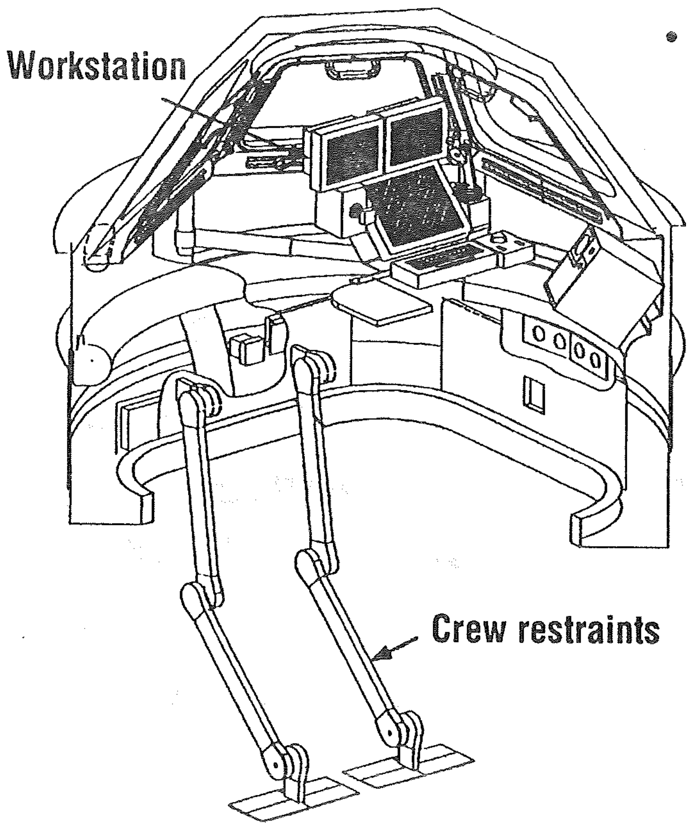
Length = 540.00"
Width = 193.00"
Height = 165.74"

MB-3



Space Station Freedom

Cupola



- One Workstation
  - New workstation configuration
    - PDR: 2-14", 5-10" displays
    - 2x6 DOF hand controllers
    - Programmable display
    - Pushbuttons,
    - master alarm lights

    - DPDR: 1-14", 2-10" displays
    - 2x3 DOF handcontrollers
    - no programmable display
    - pushbuttons,
    - no master alarm lights

MSS Development Status

- Engineering model hardware manufacturing 70% complete
- Detailed flight system design for MB 3 deliverables 35% complete
- Engineering development facilities in operation
  - Simulation facility (MDSF)
  - SPDM test rig
  - Full-scale mockups

Canadian Program Status

Program is fully funded at $1.2B until year 2000

Mobile servicing system development

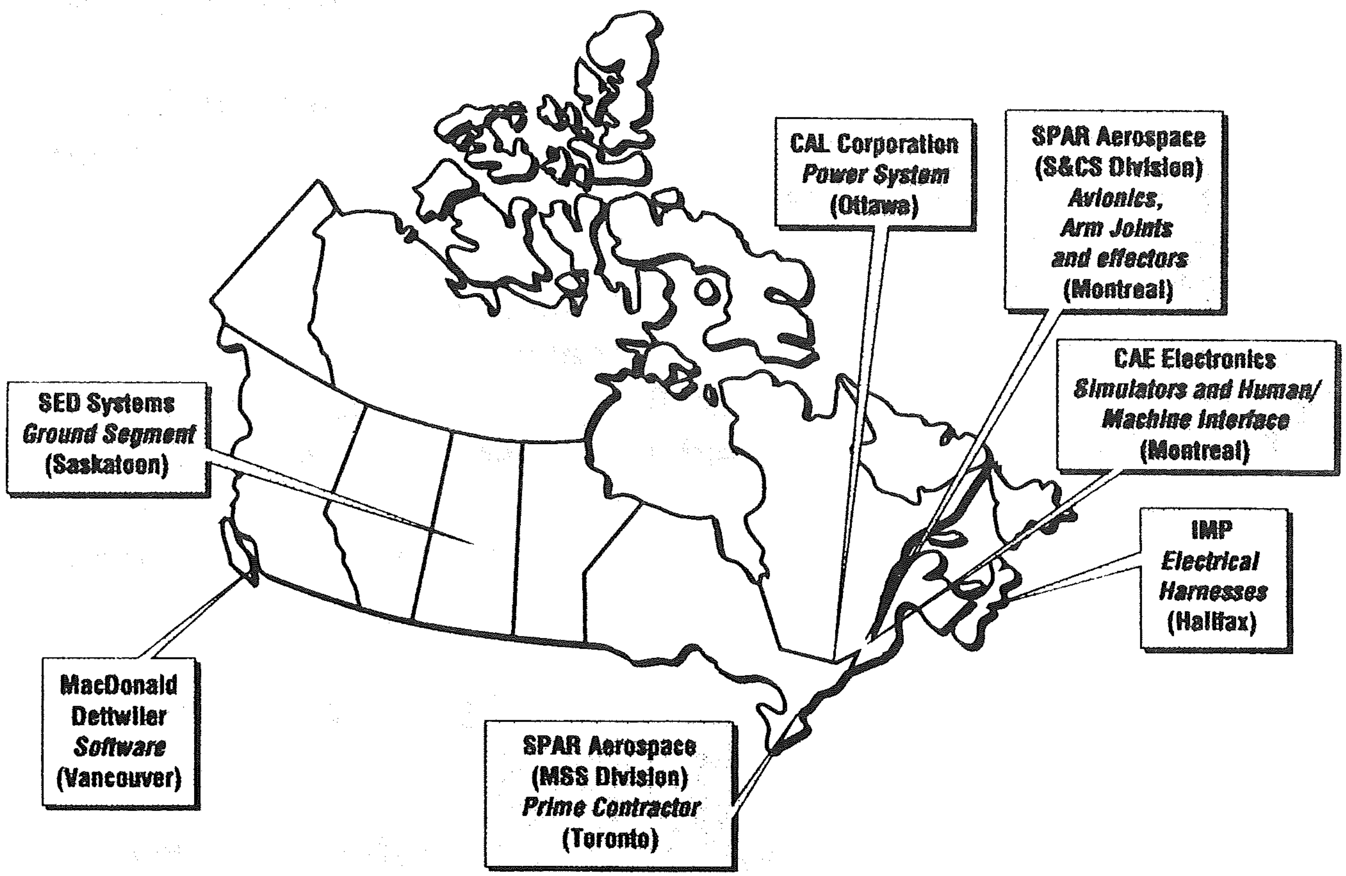
Phase A	Program definition (completed)	1984-85
Phase B	Concept development (completed)	1985-87
Phase C1	Preliminary design (completed)	1987-90
Phase C2	Detailed design (in progress)	1990-92
Phase D	Manufacture and test	1992-95
Phase E	Launch of 1st Canadian element (MB-3)	1996
	Operations Phase	1996-2025

User development

- Ongoing program

Technology development

- Ongoing program



CAL Corporation
Power System
(Ottawa)
SPAR Aerospace
(S&CS Division)
Avionics,
Arm Joints
and effectors
(Montreal)
CAE Electronics
Simulators and Human/
Machine Interface
(Montreal)
IMP
Electrical
Harnesses
(Halifax)
SED Systems
Ground Segment
(Saskatoon)
MacDonald
Dettwiler
Software
(Vancouver)
SPAR Aerospace
(MSS Division)
Prime Contractor
(Toronto)

Strategic Development

- Development of strategic technologies and industry for MSS
- Space station operations and utilization
- Space station user development
- Space station evolution

Strategic Technology Development

- Areas of technology
  - Automation of operations
  - Automated power management
  - Autonomous robotics
  - Enhanced space vision systems
  - Trajectory planning and collision avoidance
  - Protection of materials in space
  - Tactile sensors

User Development Program

- Objective: To develop potential users of the microgravity environment on Space Station, with emphasis on potential commercial applications and the necessary underlying science, especially in materials science and biotechnology

User Development Program

- Areas of current interest
  - Fluid dynamics
  - Chemistry
  - Crystal growth
  - Metals and alloys
  - Glasses and ceramics
  - Biotechnology
  - Combustion

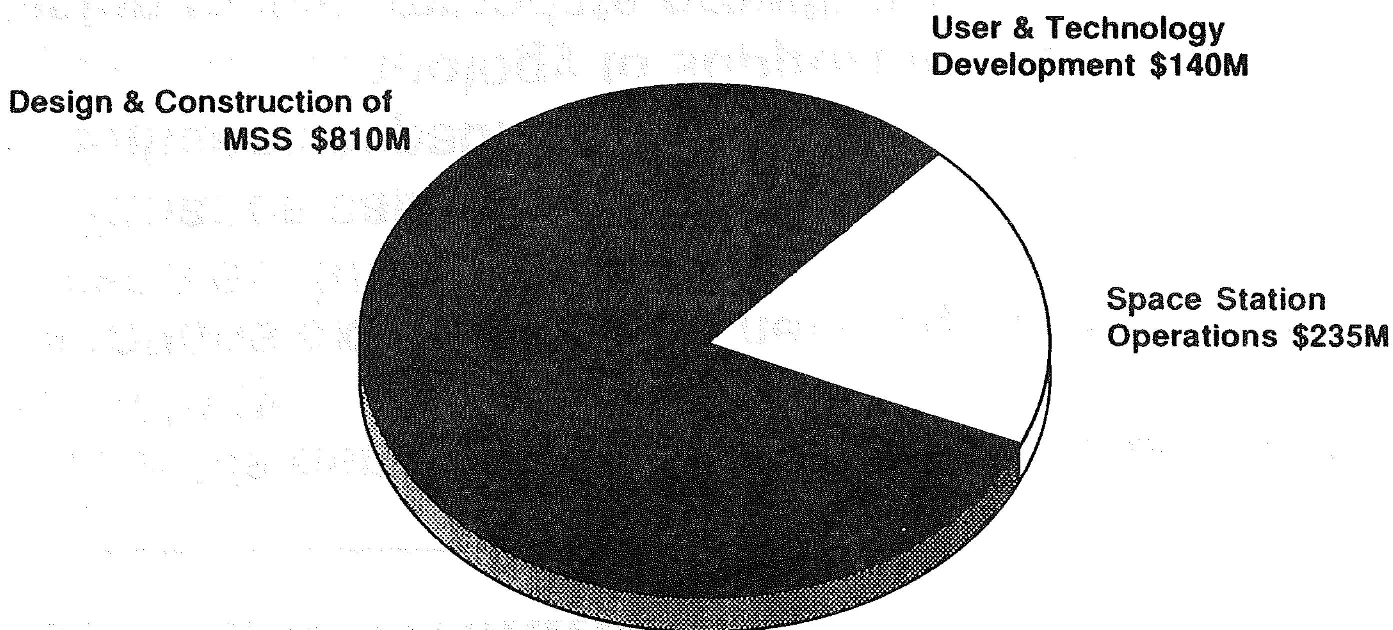
77

Growth and Evolution

- 30 year life demands incorporation of advances in technology
- Operations experience and new requirements will demand evolution
    - Enhance capacity
    - Enhance capability
    - Evolve technology to support future missions
- Design to accommodate growth and evolution
- Pursue restructured space station development
- Achieve on-orbit operational experience as soon as possible

Space Station Program Budget

1.185 billion 15 year total (1985-2000)

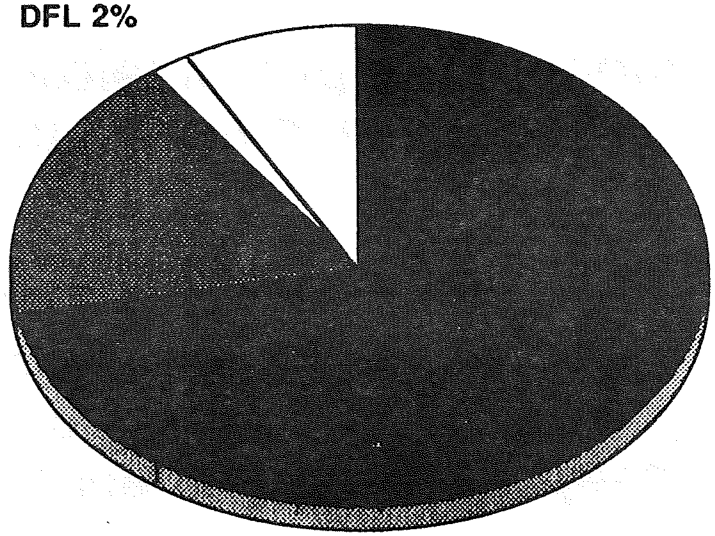


Canada's Future Space Activity

- Long term space plan is being developed for spring 1992 to provide options for Canada's future space participation
- International participation is a key factor in major programs
- Space station remains as a test case for future large scale projects and international cooperation

CSA Approved Budget $2.7B

1988/89-2000/01



NASA

SEI: AN UPDATE

PRESENTED AT
SECOND SYMPOSIUM ON SPACE STATION EVOLUTION

JOHNSON SPACE CENTER

Lewis L. Peach, Jr.
Assistant Director for Exploration (Program Definition)

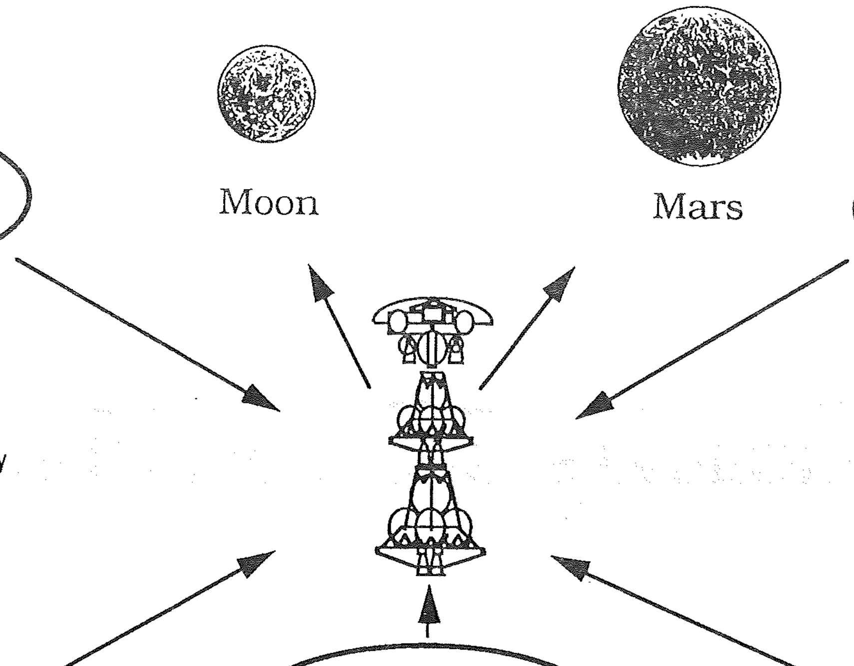
August 6, 1991

Office of Aeronautics, Exploration and Technology

Barrios2/Peach/SEI Update/SSF Evolution

NASA

HUMAN EXPLORATION - KEY PREREQUISITES



Exploration Technology Program

- Options Enabling Mission Decisions
- Opportunities in Propulsion, Power, & Robotics
- Human Performance Capability

Robotic Missions

- Acquire Science & Engineering Data, Test Critical Systems & Technologies
- Select landing sites
- Define Environment in Which Spacecraft & Crews Must Function

Human Support

- Permit Safe, Productive Long Duration Stays for Humans in Space
- Provide Understanding of Issues, Capabilities, & Limits Associated with Zero-G & Artificial-G Space Flight

Space Station Freedom

- Life Science Research Program
- Technology Development Test Bed
- Operations Experience Base
- Possible LEO Transportation Node

Heavy-lift Launch Vehicle

- Earth to orbit transportation
- New Launch System

NASA

SEI AND THE SYNTHESIS (STAFFORD) GROUP

NASA

OUTREACH AND SYNTHESIS PROCESS

OUTREACH

	Preparation	Generation of Ideas	Receipt of Ideas	Technical Review
Direct Solicitation • *Letters* • *CBD*			RAND • Sorting • Acknow-ledgement	RAND • Technical review and analysis
Review of Federally Sponsored Research	NASA Admin. Letter	Agency Briefings	Selected Facility Briefings and Visits	
AIAA Study	Study	Preliminary Analysis	Report and Conference	

NASA, industry, and others

SYNTHESIS

- Performed by group with membership from NASA, DOD, DOE, others
- Reports to NASA Administrator, who selected chairman
- Analytical support provided by NASA, DOD, DOE and others upon request

Architecture Options

Technology Priorities

Early Accompl.

NASA

SYNTHESIS STATUS

- Report delivered to Vice President Quayle and NASA Administrator on June 11, 1991
- Four distinct "architectures" (approaches) for SEI
- Fourteen long-lead critical technologies identified . . .
- Assumes major role of lunar phase is test-bed for Mars systems
- Supports Space Station Freedom as essential for life science research
- Initial assessment of Report in progress
- Formal study initiated July 1, 1991

NASA

SYNTHESIS GROUP REPORT

ARCHITECTURES

- **Mars Exploration**
  - Emphasis on Mars, lunar activities simply support Mars missions
- **Science Emphasis for the Moon and Mars**
  - Exploration of both Moon and Mars, using the Moon as an observation platform
- **The Moon to stay and Mars Exploration**
  - Emphasis on a human presence on the Moon, with smaller crews engaged in exploration and science at Mars
- **Space Resource Utilization**
  - Emphasis on developing lunar resources for energy on Earth and for launch vehicle propellants

SCHEDULE ARCHITECTURE MILESTONES

SYNTHESIS ARCHITECTURES

Mars Exploration

MS = Mars Simulation 120 days in lunar orbit (LO), 30 surface; second support crew on surface 90 days

	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
☽															☽ IOC **6** / 14		**6** / 45-60		MS **6** (2)	**6** / ?	**6** / ?									
♂								O (2)					R		R									♂ IOC **6** / 30-100		**6** / 600		**6** / 600		**6** / 600

Science Emphasis for Moon and Mars

MS = 200 days in LO, 30 surface; second support crew on surface 90 days

	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
☽									O		N		☽ IOC **6** / 14	**6** / 14	**6** / 14	**6** / 90	**6** / 180		MS **6** (2)	**6** / ?	**6** / ?		**6** / ?		**6** / ?					
♂								O (2)					R		R		N							♂ IOC **6** / 30-100		**6** / 600		**6** / 600		**12** / 600

Moon to Stay and Mars Exploration

MS = 120 days in LO, 30 surface; support crew already on surface

	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
☽										O (2)		R		☽ IOC **6** / 14	**6** / 40	**6** / 90 (2)	**6** / 365 (2)	**6** / 365 (2)	MS **6** (4)	**6** / 365 (3)	3 lunar missions/yr. continue									
♂								O (2)					R		R									♂ IOC **6** / 30-100		**6** / 600		**6** / 600		**6** / 600

Space Resource Utilization

MS = 460 days in LO, 40 surface; second support crew on surface 180 days

	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
☽									O (2)			R		☽ IOC **6** / 14		**6** / 45		**6** / 100		**6** / 180	MS **6** (2)		**12** / ?		**12** / ?		**12** / ?			
♂								O (2)					R		R											♂ IOC **6** / 30-100		**6** / 600		**6** / 600

LEGEND
O = Orbiter R = Rover N = Network IOC = Initial Operational Capability (First Crewed Mission) ( ) = Number Annual Missions ▩ = Optional Mission

Number Key
Bold = Crew Size
Plain = Days on Surface

NASA

SYNTHESIS GROUP REPORT

SUPPORTING TECHNOLOGIES

1. Heavy lift launch with a minimum capability of 150 metric tons with designed growth to 250 metric tons
2. Nuclear thermal propulsion
3. Nuclear electric surface power to megawatt levels
4. Extravehicular activity suit
5. Cryogenic transfer and long term storage
6. Automated rendezvous and docking of large masses
7. Zero gravity countermeasures
8. Radiation effects and shielding
9. Telerobotics
10. Closed loop life support systems
11. Human factors for long duration space missions
12. Lightweight structural materials and fabrication
13. Nuclear electric propulsion for follow-on cargo missions
14. In situ resource evaluation and processing

Office of Aeronautics, Exploration and Technology

RECOMMENDATIONS

(1) Establish within NASA a long range strategic plan for the nation's civil space program, with the Space Exploration Initiative as its centerpiece.

(2) Establish a National Program Office by Executive Order.

(3) Appoint NASA's Associate Administrator for Exploration as the Program Director for the National Program Office.

(4) Establish a new, aggressive acquisition strategy for the Space Exploration Initiative.

(5) Incorporate Space Exploration Initiative requirements into the joint NASA-Department of Defense Heavy Lift Program.

(6) Initiate a nuclear thermal rocket technology development program.

(7) Initiate a space nuclear power technology development program based on the Space Exploration Initiative requirements.

(8) Conduct focused life sciences experiments.

(9) Establish education as a principal theme of the Space Exploration Initiative.

(10) Continue and expand the Outreach Program.

NASA

NEAR-TERM STRATEGY FOR SEI

- Analyze alternative mission architectures
- Perform wide array of system level studies
- Continue critical technology development
- Define enabling science requirements and opportunities for SEI science
- Focus key enabling activities that are transparent to architecture:
  - Human support research
  - Lunar/Mars robotic missions
  - Heavy-lift launch vehicle
  - Advanced propulsion and power

Near-term goals

- Definition of program options to support national decision
- Development of integrated architecture independent program plan
- Initiate critical near/far-term enabling activities

Office of Aeronautics, Exploration and Technology

NASA

HUMAN SUPPORT
OBJECTIVE AND STRATEGY

Objective

- Develop SEI science, technologies, and procedures to satisfy requirements for crew life support and health maintenance

Strategy

- Characterize human needs to be met and risks encountered on SEI missions
- Determine acceptable biomedical, environmental and performance parameters for crew health, safety, and productivity
- Develop, and verify ground-based models, simulations, and assessment methods
- Develop, test, and validate technologies including risk abatement measures

HUMAN SUPPORT ELEMENTS

Science, Technology and Operations will be integrated within each element to provide the required human support

SSF • ***Zero Gravity Countermeasures and Artificial Gravity***
- Understand mechanisms underlying physical debilitation and develop countermeasures
- Determine adequacy of countermeasures on SSF
- In parallel, develop artificial gravity concepts and simulations using ground based research and SSF

• Radiation Health and Radiation Protection
- Develop Solar Energetic Particle prediction capability
- Develop and validate measures of biological effects of galactic cosmic rays
- Develop and validate materials shielding analysis codes
- Characterize shielding materials in a design database
- Define shielding and other radiation countermeasure requirements
- Validate radiation health requirements using LIFESAT

• LIFESAT
- Two spacecraft, six missions planned around four launches; 6/96, 2/97 (2 s/c), 3/98 (2 s/c), 12/98
  - Determine the relationship between radiation and microgravity/gravitational effects on biological systems
  - Validate ground based assessments, models and simulations

SSF • ***Life Support Systems***
- Further develop applicable science and technology of regenerative life support, to include bioregenerative concepts as well as physical/chemical
- Develop and validate systems for contamination monitoring and control and for partial/full closure of air, water, food and waste, utilizing ground bases and SSF research
- Develop concepts for lunar and Mars in situ resource utilization (water, oxygen, etc.) to support exploration and other goals

NASA

HUMAN SUPPORT ELEMENTS
(continued)

- EVA (Surface)
  - Evolve planetary EVA systems to maximize productive EVA time through enhanced crew performance, more efficient portable life support functions, and improved durability, reliability, and maintainability
  - Validate surface EVA systems using developed lunar and Mars test-beds

SSF • ***Human Factors***
  - Use analog facilities (e.g., Antarctica base, undersea habitat) to develop systems and procedures that will establish a physical, psychological and sociological climate favorable to crew living and work environments
  - Verify approaches using habitat and transfer vehicle simulation facilities
  - Use Space Station Freedom and lunar outpost as validation test-beds

SSF • ***Advanced Medical Care***
  - Develop in-flight and ground-based support systems to provide remote medical care in event of injury or illness
  - Verify and validate systems using STS, SSF, lunar missions and analogs (Antarctica)

- Planetary Protection
  - Define the potential threats of planetary forward and back contamination
  - Develop, validate, and perform operational tests of protection equipment and procedures
  - Define and develop flight hardware for planetary protection management on Mars robotic and human missions

UTILIZATION OF SSF

SPACE STATION FREEDOM
SEI ACCOMMODATIONS

Objectives

- Support life sciences research and technology verification activities required for the Space Exploration Initiative
- Maintain the design flexibility to support on-orbit processing of lunar and Mars spacecraft

Strategy

- Identify architecture independent requirements on SSF to support SEI and define corresponding program
  - Primarily R&D activities (Life Sciences and technology verification)
  - Supports continued development of SSF into a life sciences and technology test-bed configuration by 2004
- Continue a broad research program which maintains Space Station Freedom development options to support architecture specific roles
  - Includes transportation node (vehicle processing) activities
  - Supports continued development of SSF into a transportation node by 2007 if needed while minimizing near-term costs
- Focus near-term efforts on advanced studies and long lead time advanced development for selected technologies

NASA

SPACE STATION FREEDOM SEI ACCOMMODATIONS (Continued)

Content

- Space Station Freedom augmentations for life sciences and R&T to support to SEI
  - Systems definition and integration studies
  - Additional habitation module for increased crew size
  - Increased power through addition of high-efficiency power generation systems (e.g., solar dynamic)
  - Subsystem upgrades associated with adding power (thermal, utility distribution, etc.)
  - Advanced technology development

- Space Station Freedom augmentations to provide SEI transportation node
  - Additional structure for attaching facilities
  - Advanced suit and second airlock for increased EVA
  - Lunar Transfer Vehicle accommodations facility
  - Cargo Transfer Vehicle accommodations (option)
  - Advanced propulsion system
  - Advanced Automation and Robotics program to reduce EVA requirements

NASA

SUMMARY

- Near-term SEI activities stress development of an integrated program plan linking SEI-related research and advanced development to mission milestones based on a "common keel" that supports all architectures
- Focused life sciences research, technology development and space qualification heavily dependent on SSF availability and evolving capabilities
- Some SEI architectures may impose special additional requirements on SSF, e.g. transportation node role, in-space servicing support for SEI mission systems

Advanced Space Transportation Systems

Space Station Evolution
Beyond the Baseline 1991
(2nd Symposium Evolution of SSF)

Robert J. Davies
Chief, Advanced Transportation Branch
Advanced Program Development
Office of Space Flight

2348

Agenda

- Heavy Lift Launch Vehicle
- Cargo Transfer Vehicle
- Space Transfer Vehicle Concepts
- Two-Way Personnel Transport
- Transportation Node Requirements
- Technology Needs

National Space Launch Strategy

a. The National Space Launch Strategy is composed of four elements:

(1) Ensuring that existing space launch capabilities, including support facilities, are sufficient to meet U.S. Government manned and unmanned space launch needs.

(2) Developing a new unmanned, but man-rateable, space launch system to greatly improve national launch capability with reductions in operating costs and improvements in launch system reliability, responsiveness, and mission performance.

(3) Sustaining a vigorous space launch technology program to provide cost effective improvements to current launch systems, and to support development of advanced launch capabilities, complementary to the new launch system.

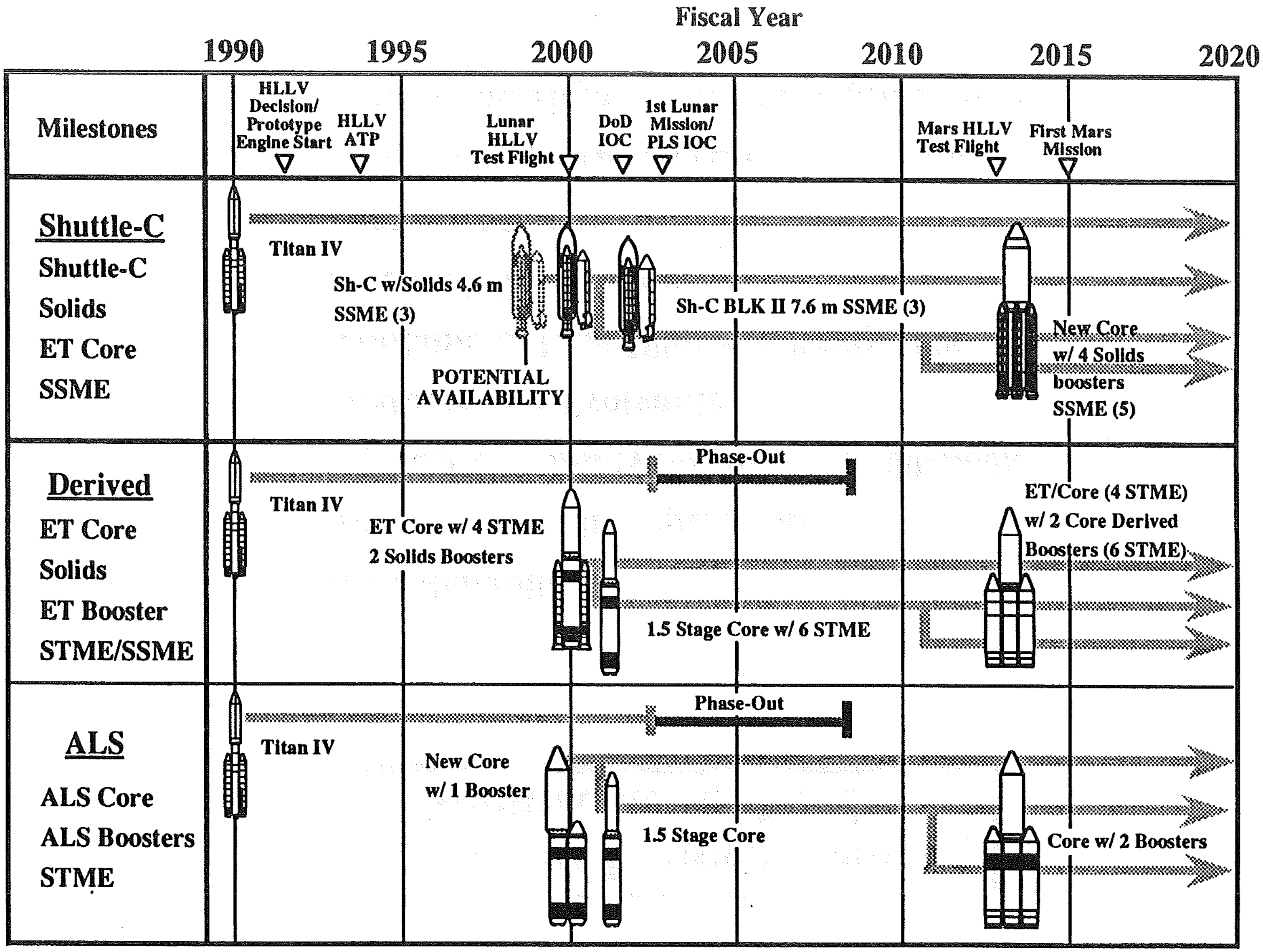
(4) Actively considering commercial space launch needs and factoring them into decisions on improvements in launch facilities and launch vehicles.

b. These strategy elements will be implemented within the overall resource and policy guidance provided by the President.

Heavy Lift Launch Vehicle Requirements/Needs

- High Reliability
- Good Availability/Operability
- Payload Capability 50–80k and 100–200k
- Modular and Evolvable
- Available in Late 1990 ~ to Early 2000
- Potential Applications
  - Space Station
  - Space Exploration (Lunar and Mars)
  - Low and High Orbit DoD Applications

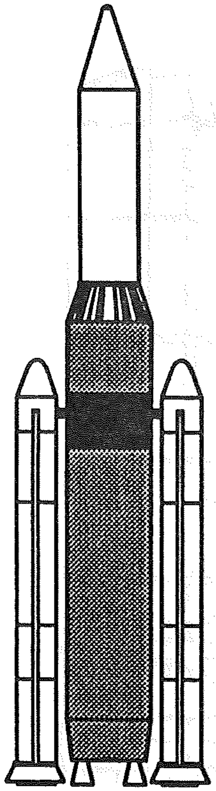
Basic Heavy Lift Vehicle Options



1811

Future Launch Vehicle Concept

HLLV

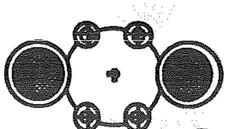


Titan IV Derived Shroud (STS Compatible)

Kickstage/CTV

ASRM's

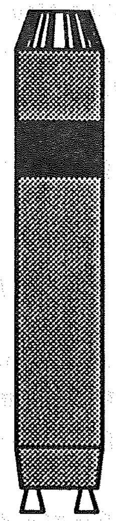
LC 39 Facilities



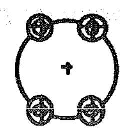
Don't Install:
- Inflight Separation Systems for 4 Outboard Engines
- Holddown Mechanisms

Common Core

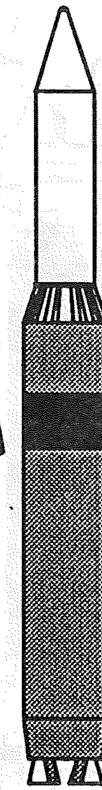
(ET Derived)



- Forward Interstage
- Forward Skirt
- Tankage/Intertank
  - Std Size/Materials
  - Beefup for 1.5 Stg Application
- Avionics
- Thrust Structure/Propulsion System
  - Inflight Separation System for 4 Outboard STME's
  - Thrust Struct/Prop.Capability for 2 Center STME's
- AFT Skirt
  - Vehicle Holddown



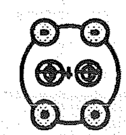
1.5 Stage



Titan IV Shroud

Upper Stage

LC 39 and LC 34 Facilities

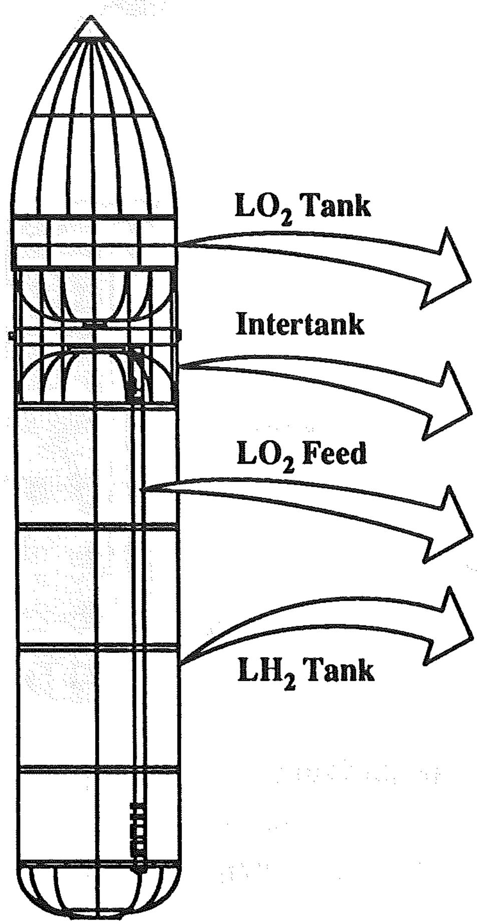


Install:
- Structure/Propulsion for 2 Center Engines
- Holddown Mechanisms

Sustainer STME's   Staged STME's

External Tank Application Potential

Std ET



Modifications/Changes

Add Avionics/Payload Adapter

Add Forward Skirt

Add Fwd Dome (Same as LH_2 Fwd Dome)
Add Barrel Section
Modify Feedline Outlet

Stiffen Panels

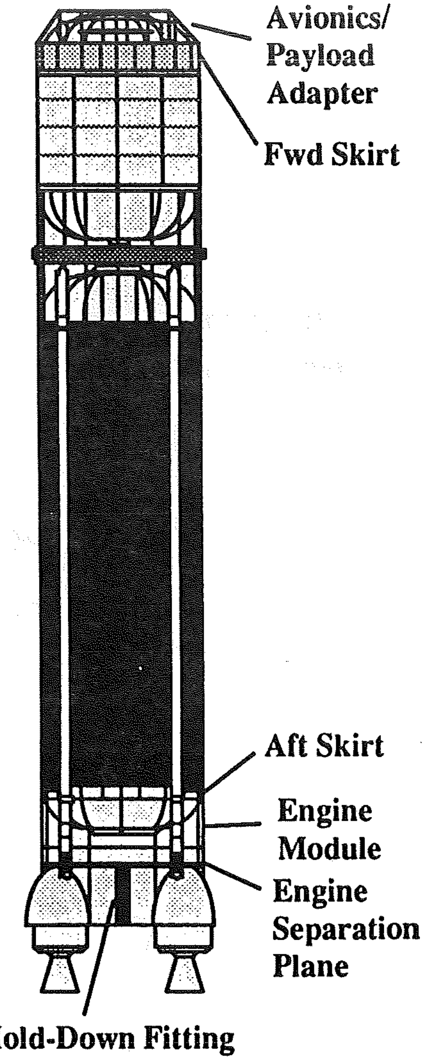
Add Feedline

Stiffen Barrels 1, 2, 3, & 4
Modify Aft Dome Frame for Engine Module Attach
Modify Feedline Outlet

Add Aft Skirt

Add Engine Module

Common Core



1.5 Stage Driven | HLLV Driven | Applicable to Both Vehicles

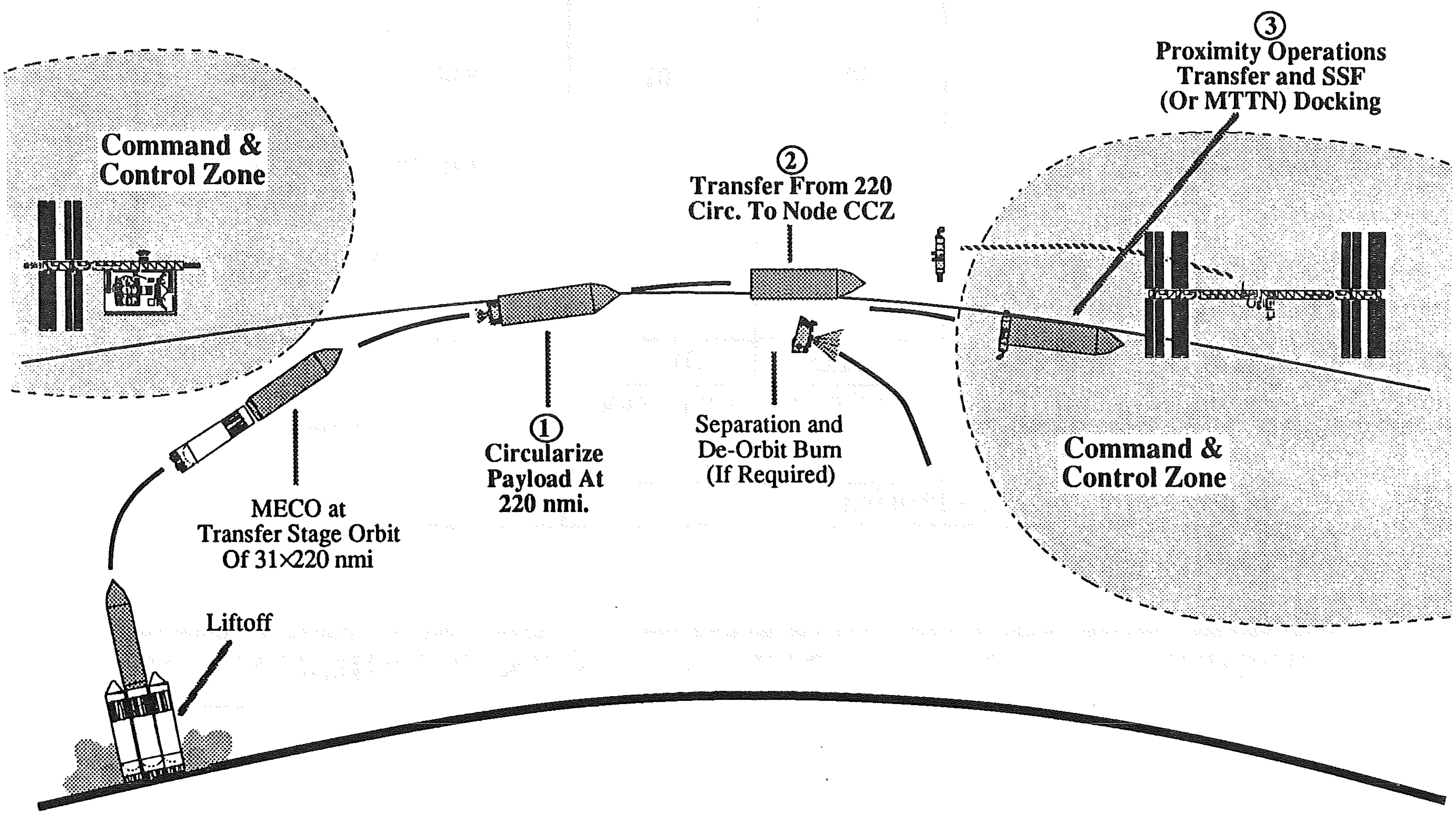
1809

Representative NLS Reference Vehicle Performance

Vehicles	Payload ~ Klbs			
	SSF Mission		80 x 150 N.M. Orbit	
	Eng. Out	No Eng. Out	Eng. Out	No Eng. Out
	STME	STME	STME	STME
HLLV (2 ASRMs)				
– Core w 3 Engines	-	117	-	-
– Core w 4 Engines	101	109	-	-
1.5 Stage (6 Engines)	14	-	49	~65
1.5 Stage (5 Engines)	-	-	-	64

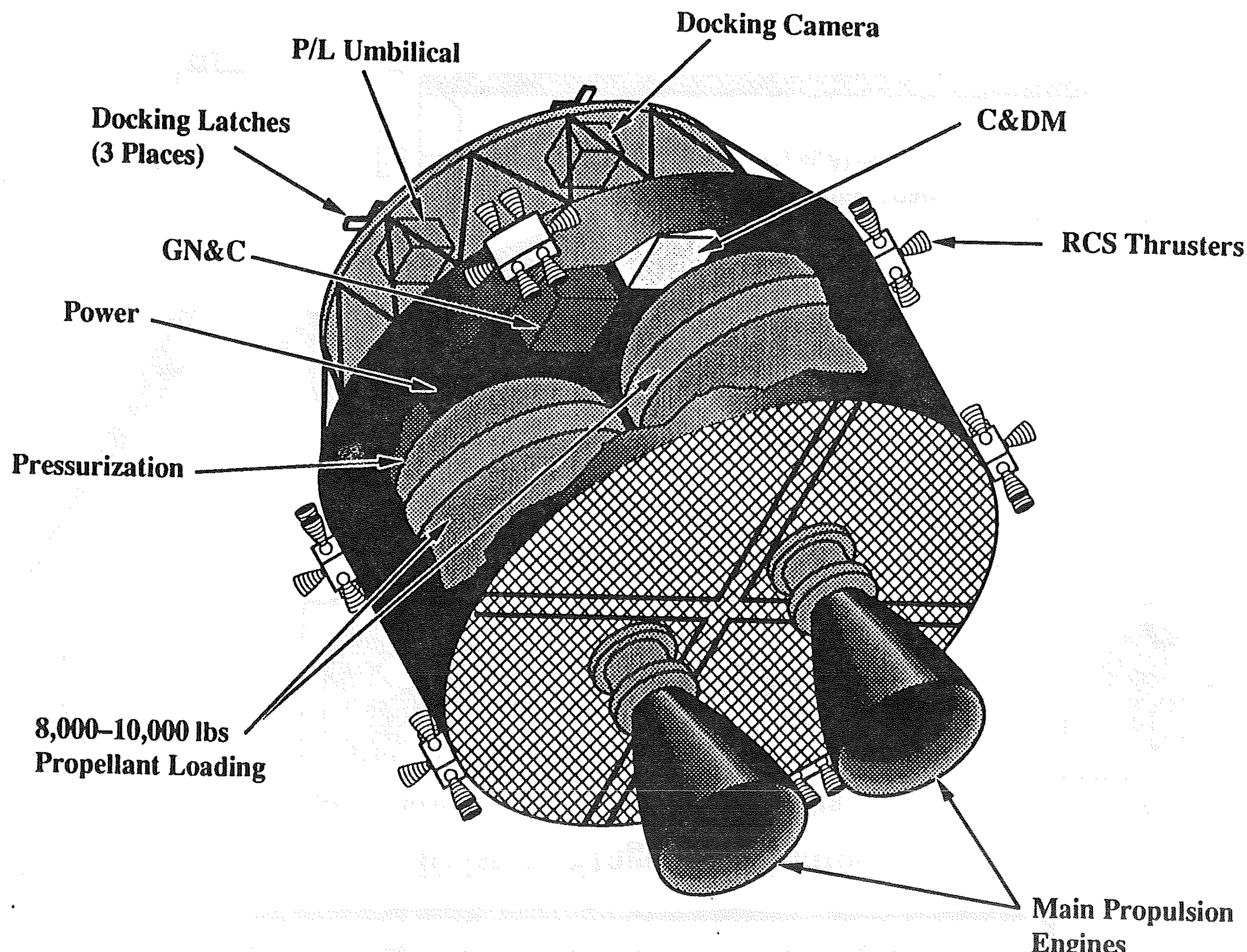
Cargo Transfer Vehicle (CTV)

In-LEO Transportation Functions



1994

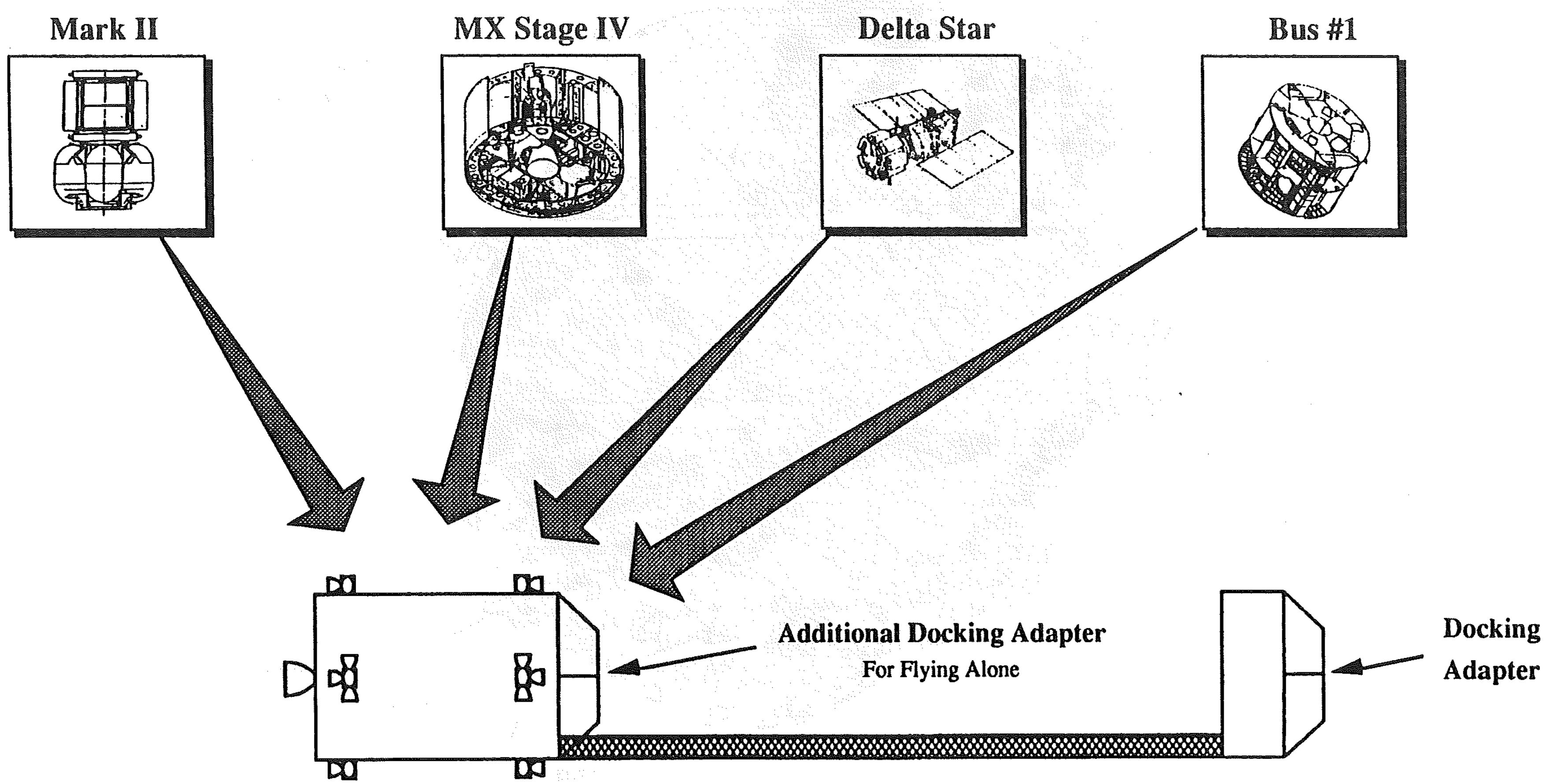
Cargo Transfer Vehicle Concept



1845

Cargo Transfer Vehicle (CTV)

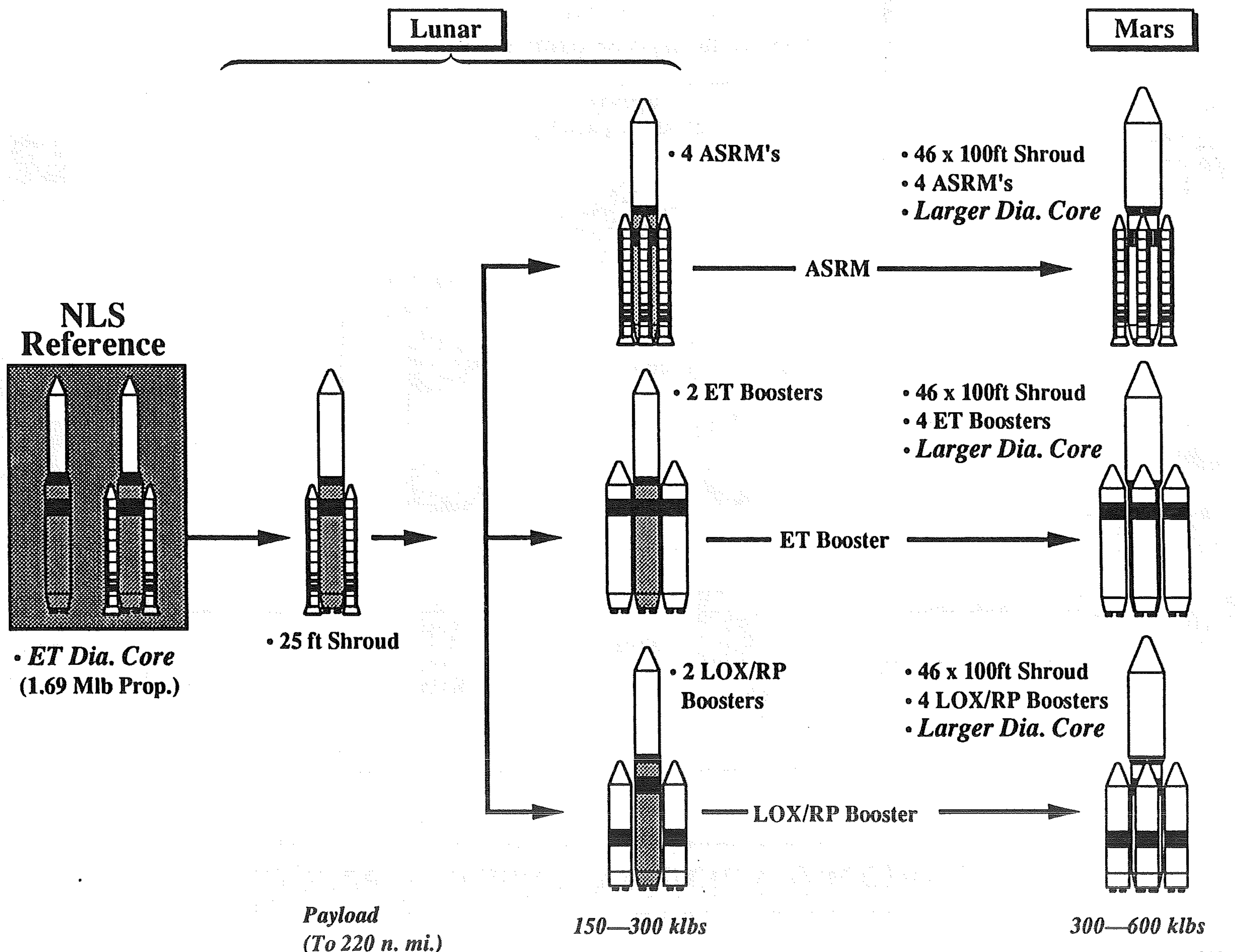
Existing Stage Candidates



Features

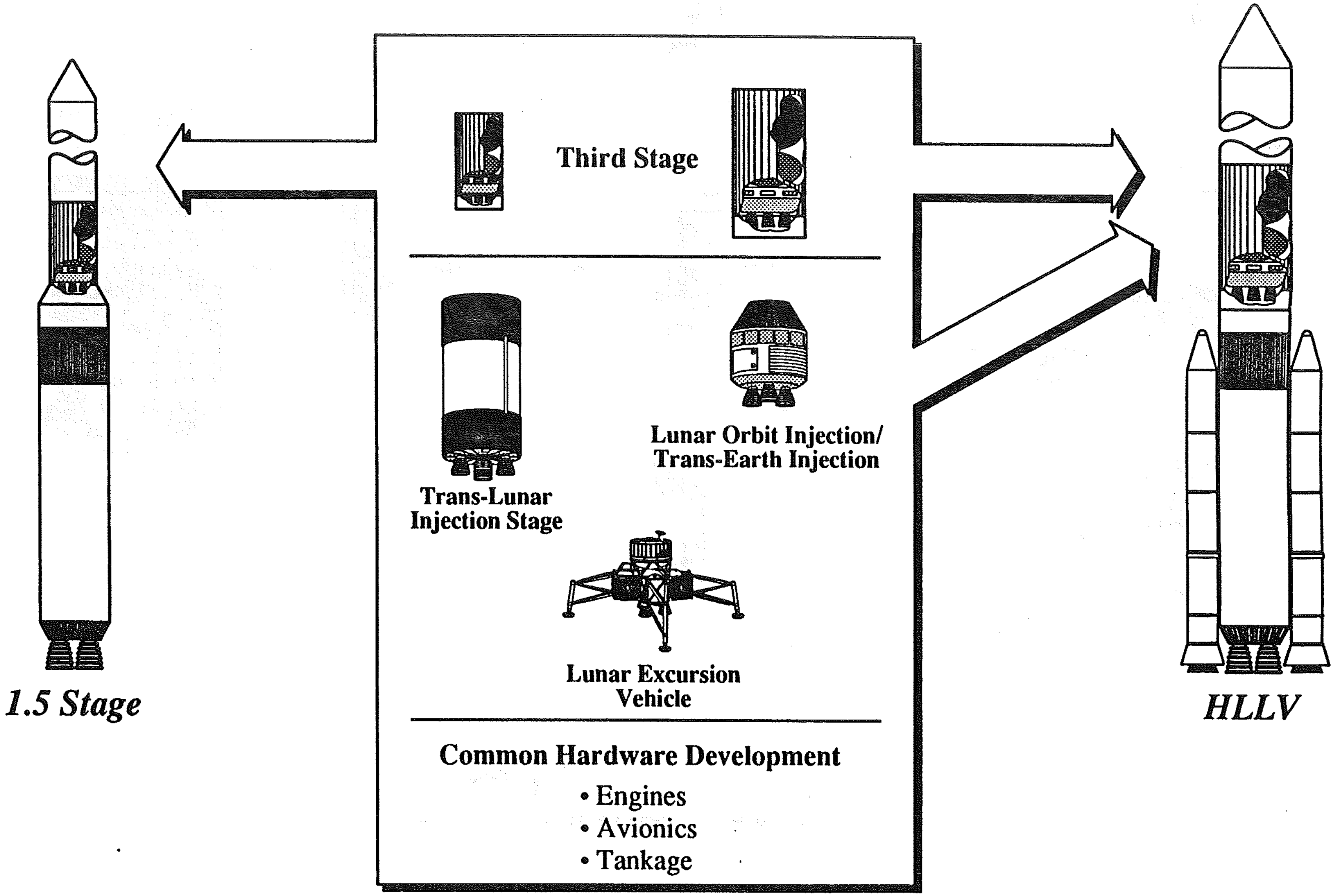
- Performs Circularization & Phasing Burns
- Controls During Prox Ops
- Deorbits Strongback & Recovers
- Independent Return Flight to SSF
- Returns on STS

Evolution Flow



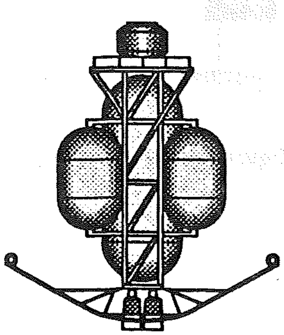
1808 a

Space Transfer Vehicle Concepts

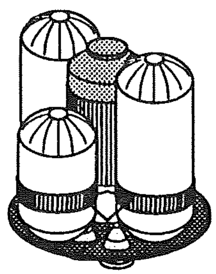


Lunar Transportation Options

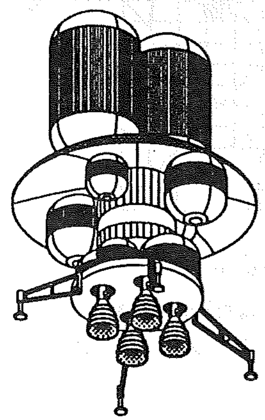
Lunar Transfer



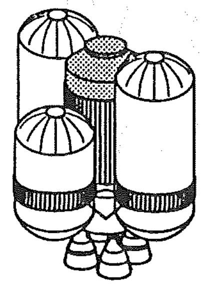
Chemical/Aerobrake
Single Stage



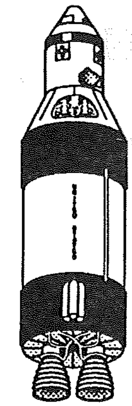
Chemical/Aerobrake
1 1/2 Stage



Chemical/Aerobrake
Single P/A

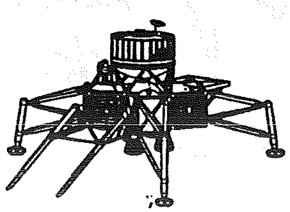


Chemical - All Propulsive
Module w/Recoverable P/A

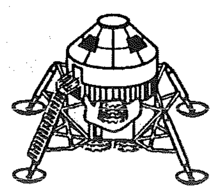


Chemical - All Propulsive
Expendable

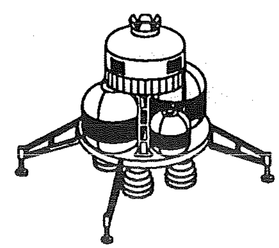
Lunar Lander



Single Stage



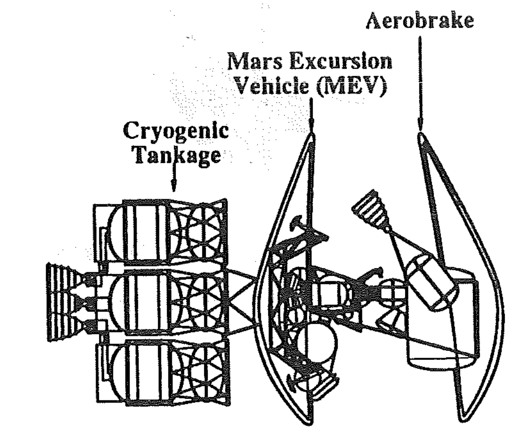
Two Stage



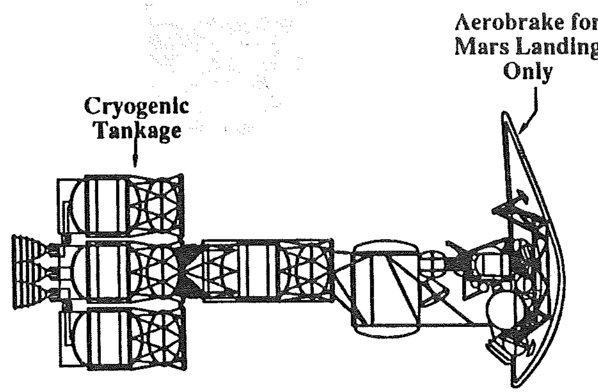
Single P/A

* Not to Scale *

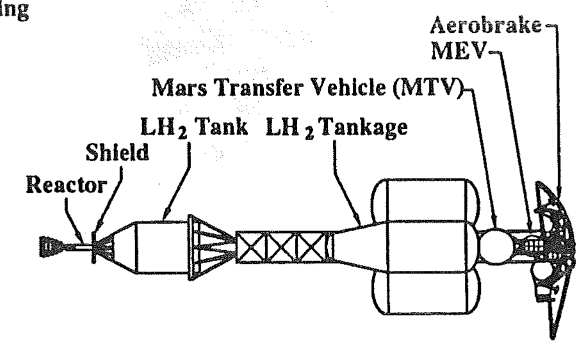
Mars Transportation Options



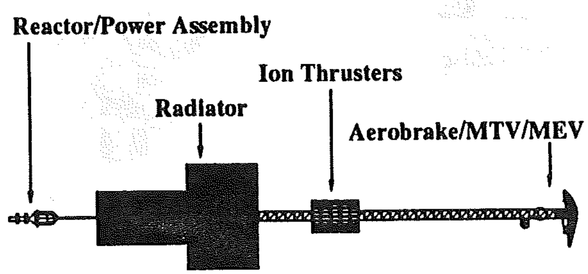
Cryogenic/Aerobrake Reference Configuration



Cryogenic/All Propulsive Configuration

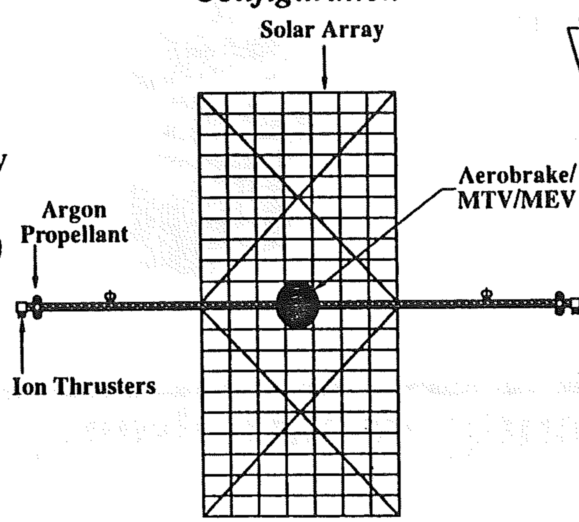


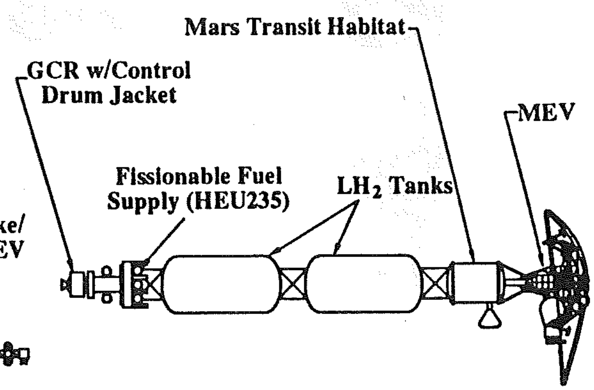
Nuclear Thermal Propulsion Configuration



Nuclear Electric Propulsion Configuration

Solar Electric Propulsion Configuration





Gas Core Nuclear Reactor Configuration

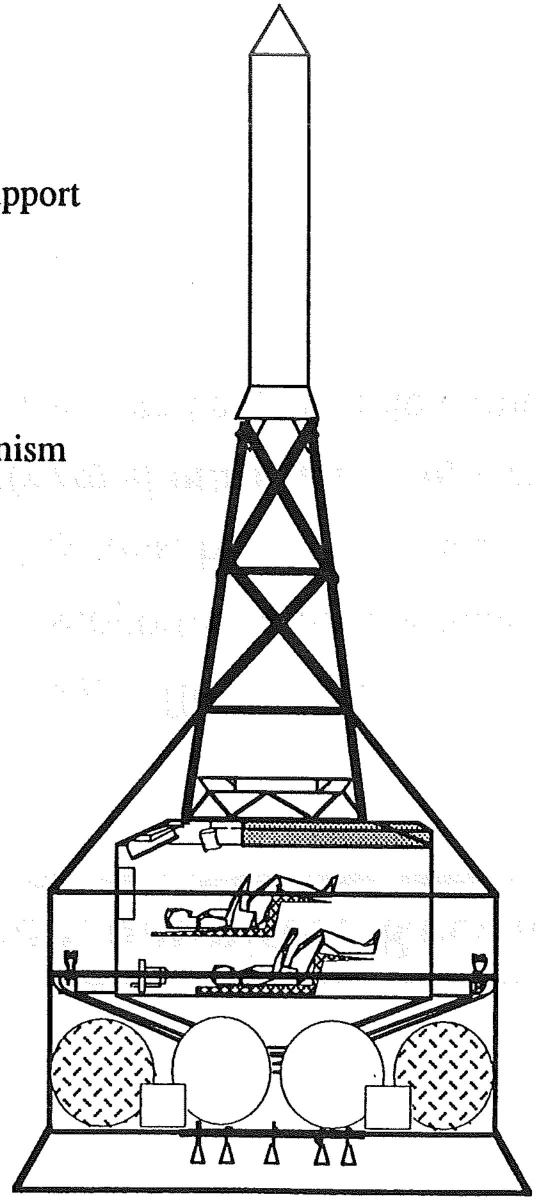
1815

Augustine Committee Recommendation

"That NASA initiate design effort so that manned activity in the Space Station could be supported in the absence of the Space Shuttle. Crew recovery capability must be available immediately, and ***provision made for the relatively rapid introduction of a two-way personnel transport module*** on a selected expendable launch vehicle.

ACRV-D Baseline Concept

Summary of Design Deltas from ACRV-CERV



Crew Module

(12,000 to 15,000 lbm)

New Components

- External Structure for LES Support
- 2 string laser docking system
- Hand controllers

Replaced Components

- Berthing with docking mechanism

Increased Components

- 2 more battery modules
- 1 more EPDC string
- ECLSS LiOH expendables
- 2 more RCS jet drivers
- S-band data capability
- UHF voice comm capability
- 1 more multi-function display
- 2 more GPS strings
- Parachute size
- 33% more wiring

Service Module

(2900 to 7400 lbm)

New Components

- Cold gas RCS

Replaced Components

- Hydrazine with MMH/NTO
- Integrated OMS/RCS system

Increased Components

- 5 more battery modules
- 1 more EPDC string
- ECLSS consumables
- 33% more wiring

Additional Elements

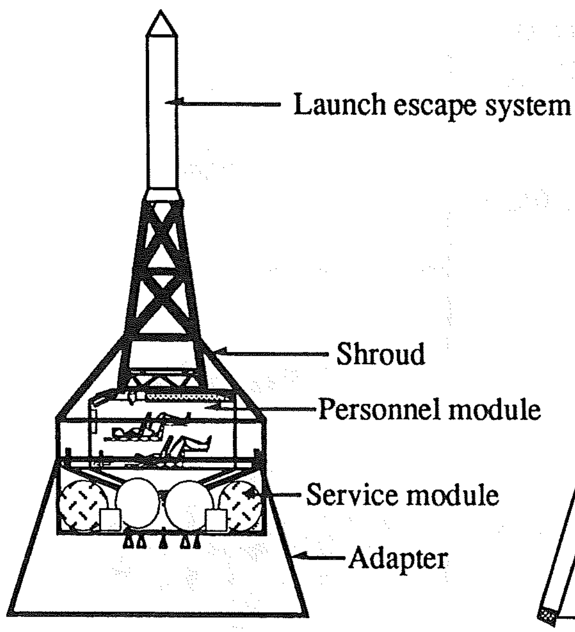
- Launch Escape System (4750 lbm)
- Launch Shroud (900 lbm)
- Launch Vehicle Adapter (160 lbm)

Liftoff Mass

28,210 lbm

2346

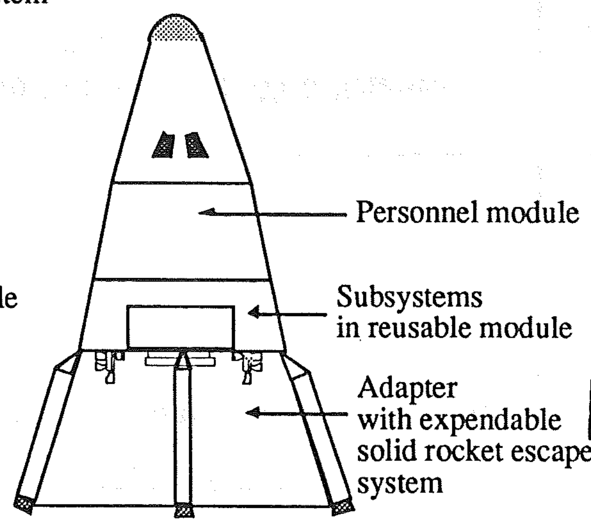
Two-way Transportation System Options



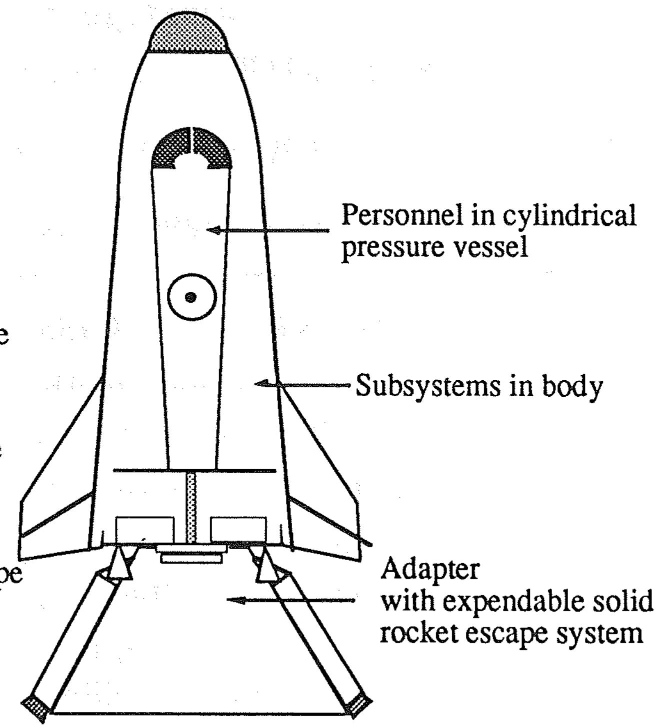
ACRV-derived

(ACRV-D)

- JSC Inhouse Design
- SCRAM Based with more robust Service Module



Biconic

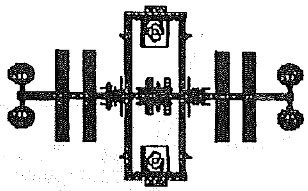
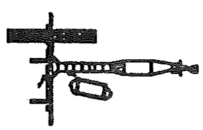
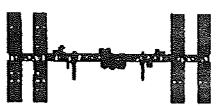


HL-20

Lifting Body

- LaRC Preferred Concept

SEI Transportation Nodes Options

	PRO's	CON's
 SSF Based	• Enhanced SSF Utilization • No New Major SSF Elements • No Crew Transfer For Operations	• Additional Free Flying Science Platforms • Dynamic μ-g environment may Interfere With Science • Assembly Intensive Philosophy • Increased SSF Resource Requirements • SSF Hooks And Scars
  Free Flying Node	• No Interference With Science Programs • Removes Potentially Hazardous Systems (Nuclear, Etc.) • Reduced Schedule Risk • No Propellant Venting at SSF • Node Utilizes SSF Hardware	• Man Tended System • New Platform Required • Crew Transport for EVA Contingencies • Additional Logistics Operations

2342

Technology Needs

- Launch Vehicles
  - Propulsion
  - Avionics
  - Materials
  - Operations

- Space Transfer Vehicles
  - Propulsion
  - Avionics
  - Aerobraking
  - Cryogenic Fluid Storage and Transfer

National Aeronautics and
Space Administration

SPACE STATION FREEDOM EVOLUTION SYMPOSIUM

RICHARD H. OTT
DIRECTOR, COMMERCIAL DEVELOPMENT DIVISION
OFFICE OF COMMERCIAL PROGRAMS

AUGUST 6, 1991

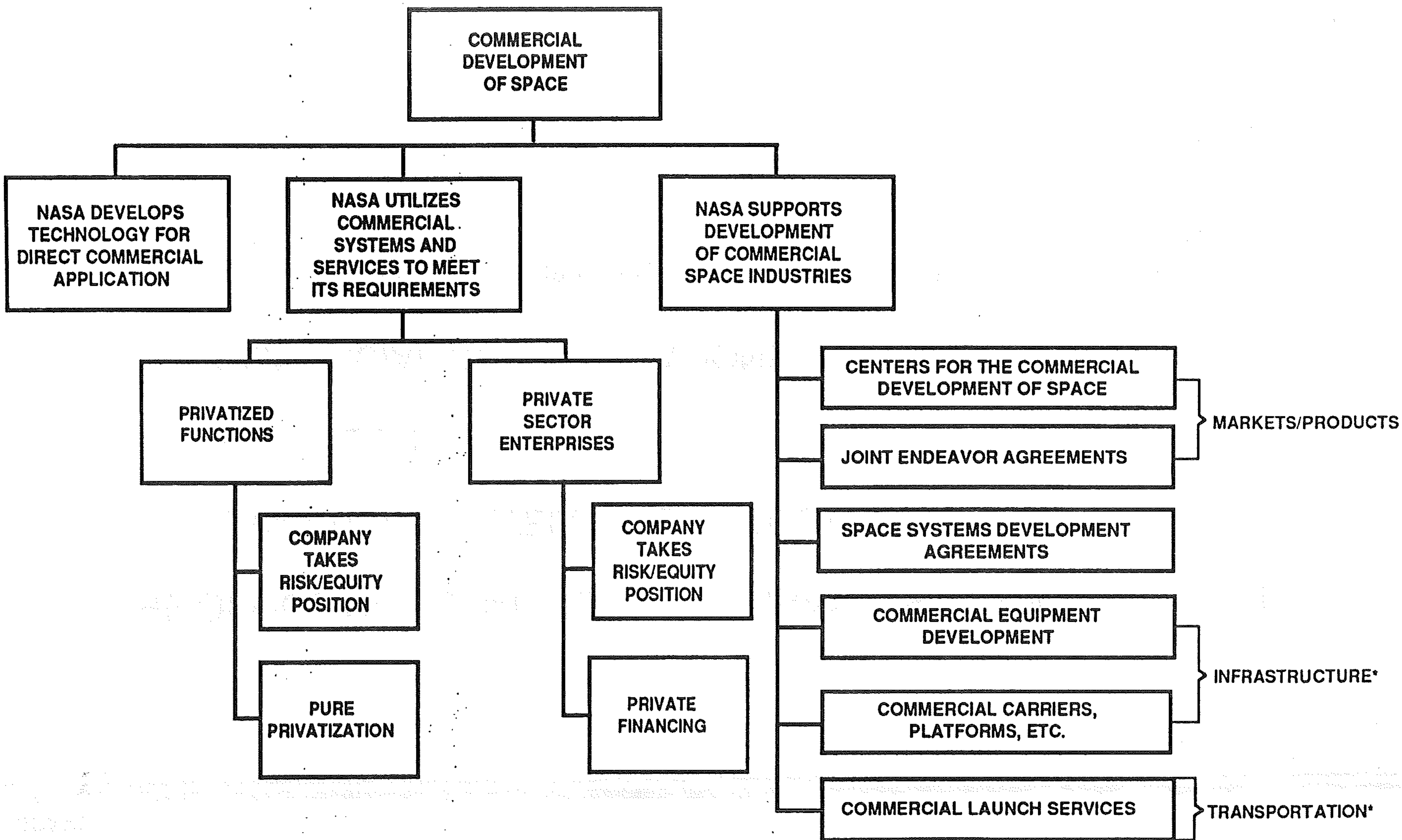
RESPONSIBILITIES

THE OFFICE OF COMMERCIAL PROGRAMS IS RESPONSIBLE FOR:

- COMMERCIAL DEVELOPMENT OF SPACE
- TECHNOLOGY UTILIZATION
- COMMERCIAL COMMUNICATIONS SYSTEMS
- SMALL BUSINESS INNOVATION RESEARCH PROGRAM

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

NASA'S ACTIVITIES IN COMMERCIAL DEVELOPMENT OF SPACE



NOTE: DIRECTLY SUPPORT DEVELOPMENT OF MARKETS AND PRODUCTS

CP- 4398B 5/22/90—TEM

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

INDUSTRY DEVELOPMENT NEEDS AND OFFICE OF COMMERCIAL PROGRAMS STRATEGY

- GIVEN
  - PRIVATE MARKETS/PRODUCTS MUST BE DEVELOPED IF TRUE COMMERCIAL DEVELOPMENT IS TO HAPPEN
  - SATELLITE COMMUNICATIONS AND MICROGRAVITY TECHNOLOGIES WILL STIMULATE THE GROWTH OF PRIVATE MARKETS
  - PRIVATE MARKET ENTERPRISES ARE THE FUTURE CUSTOMERS FOR TRANSPORTATION AND INFRASTRUCTURE ENTERPRISES

- STRATEGY
  - THE GOVERNMENT MUST CONCENTRATE ITS ASSISTANCE AND RESOURCES ON STIMULATING NEW SPACE MARKET DEVELOPMENTS
  - THE GOVERNMENT SHOULD SUPPORT TRANSPORTATION AND INFRASTRUCTURE VENTURES THAT CAN DIRECTLY CONTRIBUTE TO DEVELOPMENT OF NEW MARKETS OR BE TRANSITIONED IN THE FUTURE FROM GOVERNMENT TO PRIVATE USE
  - GET INDUSTRY DIRECTLY INVOLVED IN PLANNING AND OVERSIGHT OF NATION'S COMMERCIAL SPACE ACTIVITIES

CP-4376 10/2/90—TEM

THREE-PHASE PROGRAM TO DEVELOP COMMERCIAL SPACE

PHASE I

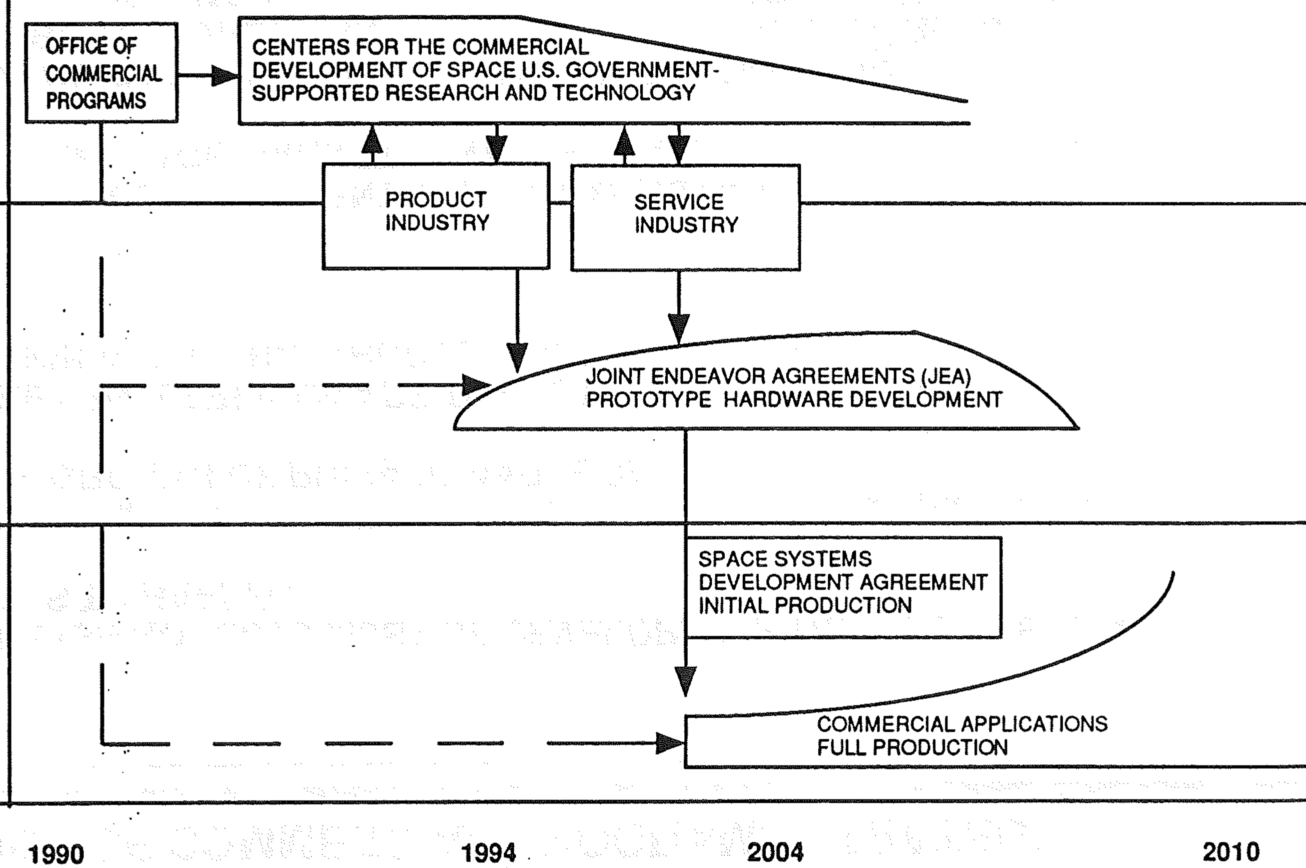
- GOVERNMENT GRANTS FOR SPACE-RELATED, INDUSTRY-DRIVEN RESEARCH
- TECHNOLOGY DATA BASE DEVELOPMENT
- DEVELOPMENT OF COMMERCIAL SPACE TRANSPORTATION AND INFRASTRUCTURE

PHASE II

- TECHNOLOGY DEVELOPMENT BY INDUSTRY FOR NEW COMMERCIAL MARKETS
- UNIQUE INDUSTRY/GOVERNMENT COLLABORATION—JEA
- EXPANDED INFRASTRUCTURE DEVELOPMENT, INCLUDING AUTOMATED FACILITIES

PHASE III

- TECHNICAL APPLICATIONS BROUGHT TO MARKETPLACE
- GOVERNMENT SUPPORT AND OPERATION OF INDUSTRY REQUIRED INFRASTRUCTURE
- PRIVATE SECTOR PROCURES ITS OWN GOODS AND SERVICES



CA-0465 4/25/91

NASA
OFFICE OF COMMERCIAL PROGRAMS

CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE (CCDS)

DESCRIPTION:

CCDS'S ARE JOINT UNDERTAKINGS INVOLVING TEAMS OF U.S. INDUSTRY, UNIVERSITY, AND OTHER NON-NASA GOVERNMENT

OBJECTIVE:

PROVIDE A PATHWAY FOR U.S. INDUSTRY TO DEVELOP COMMERCIAL MARKETS USING THE ATTRIBUTES OF SPACE

- NEW PRODUCTS
- NEW SERVICES
- NEW PROCESSES

CRITERIA:

CONSORTIA OF INDUSTRY/ACADEMIA/GOVERNMENT

INDUSTRIALLY DRIVEN RESEARCH AND DEVELOPMENT

COMMITMENT OF NON-NASA RESOURCES

NASA FUNDS AT APPROX. $1 MILLION/YEAR/CCDS PLUS SPECIFIC AUGMENTATIONS

CC-2182 7/31/90

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

COMMERCIAL USE OF SPACE PROGRAM SUMMARY – 1991

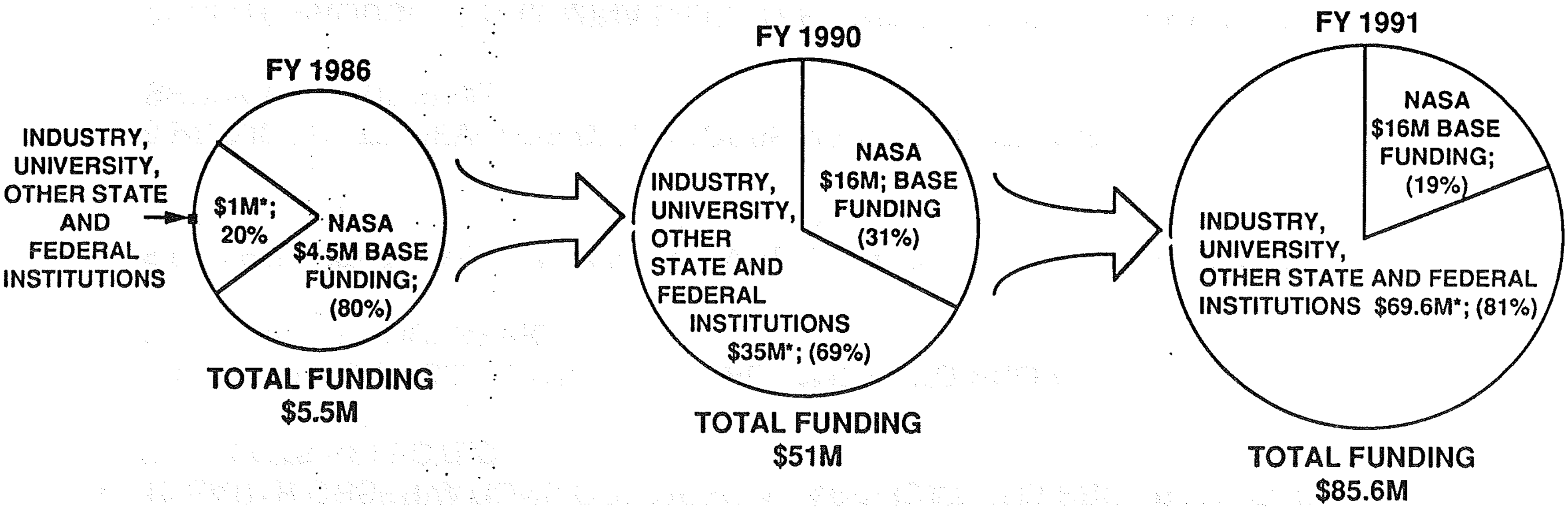
CENTER	COMMERCIAL FOCUS	AFFILIATES		
		INDUSTRY	UNIVERSITY	GOVT
MATERIALS PROCESSING IN SPACE				
BATTELLE	ELECTRONICS, POLYMER AND CATALYSTS APPLICATIONS—AEROPROPULSION, AIRFRAMES AND SPACE STRUCTURES	12	9	1
UAH	SUPERCONDUCTORS AND ELECTRO-OPTICAL MATERIALS—OPTICAL SCANNERS, SATELLITE COMPONENTS	10	0	1
VANDERBILT	METALS, ALLOYS, CERAMICS AND GLASSES—SOLAR DYNAMICS, NUCLEAR SYSTEMS, TURBINES, NOZZLE COMPONENTS	2	2	3
CLARKSON	ELECTRONICS, COMMUNICATIONS—COMPUTERS, SEMICONDUCTORS	10	6	4
HOUSTON	THIN FILM GROWTH AND MATERIALS PURIFICATION—ELECTRONICS, MAGNETIC DEVICES, COMPUTER CIRCUITS	6	4	5
SPACE STRUCTURES				
CASE WESTERN	FILMS, EXPANDABLE STRUCTURES—SPACE STRUCTURES	22	7	5
REMOTE SENSING				
ITD SRSC	PROCESSED REMOTE SENSING INFORMATION—FORESTRY, FISHERIES, AGRICULTURE	9	6	8
OHIO STATE	REMOTE SENSING SENSOR AND DISPLAY APPLICATIONS—COASTAL PLANNING, CROP STRESS, MINING	16	0	5
NASA STENNIS (EOCAP)	COMMERCIAL APPLICATION OF REMOTE SENSING DATA	49	10	11
LIFE SCIENCES				
PENN STATE	UNDERSTANDING OF CELL FUNCTIONS FOR DISEASE TREATMENT—OSTEOPOROSIS, GROWTH SYSTEM	30	0	3
COLORADO BIOSERVE	PHARMACEUTICAL, HEALTH CARE OR AGRICULTURAL PRODUCTION	33	4	3
UAB	CRYSTAL GROWTH FOR USE IN NEW PHARMACEUTICALS OR BIOTECHNOLOGY	11	17	3
ROBOTICS				
WISCONSIN	AUTOMATION AND ROBOTICS—DEXTEROUS ROBOT HANDS, INTELLIGENT, FLEXIBLE AUTOMATED SYSTEMS	10	3	2
ERIM	SENSOR AND AUTOMATED MANIPULATION TECHNOLOGY FOR HAZARDOUS ENVIRONMENTS—NUCLEAR WASTE CLEAN UP, MINING	12	1	3
AUBURN	ALTERNATIVE COMMERCIAL SPACE POWER—TRANSMISSION SYSTEMS, ADVANCED CONTROLLERS	4	3	6
SPACE POWER				
TEXAS A&M	COMMERCIAL SPACE POWER SYSTEMS—MICROWAVE TRANSMISSION, SPACE STATION FREEDOM AUGMENTATION	26	3	7
TENNESSEE	ALTERNATIVE SPACE PROPULSION TECHNOLOGIES	9	4	4
	TOTAL	271*	79*	74*
SPACE PROPULSION				

*SOME COMPANIES PARTICIPATE IN MORE THAN ONE CCDS

CC-2621 2/14/91

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

NASA IS SUCCESSFUL IN PHASE 1



NASA FUNDS, LEVERAGED BY INDUSTRY, UNIVERSITY, AND OTHER STATE AND FEDERAL INSTITUTIONS, HAVE YIELDED MANY ACCOMPLISHMENTS: 61 INDUSTRY-DRIVEN TECHNOLOGIES ARE BEING DEVELOPED TO DETERMINE COMMERCIAL POTENTIAL

- 238 INDUSTRY RELATIONSHIPS
- 72 UNIVERSITY RELATIONSHIPS
- 59 PATENTS IN PROCESS
- 865 PUBLICATIONS TO DATE
- 200 PUBLICATIONS IN WORK
- 14 SPINOFF COMPANIES/PRODUCTS
- 44 TECHNOLOGIES BEING USED BY INDUSTRY
- 1,089 DROP TUBE/DROP TOWER EXPERIMENTS COMPLETED
- 81 LEAR/KC-135 FLIGHTS COMPLETED
- 10 SHUTTLE FLIGHT TESTS COMPLETED SINCE RESUMPTION
- 19 SOUNDING ROCKET FLIGHT TESTS COMPLETED
- 64 HARDWARE SYSTEMS UNDER DEVELOPMENT FOR FLIGHT TEST

NOTE: INCLUDES IN-KIND SERVICES

CA-0087 4/23/91

CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE
COMPANY AND TECHNOLOGY SPINOFFS

- 7 SPINOFF COMPANIES WITH 2 MORE IN NEGOTIATION
- 8 DEVELOPMENT PROGRAMS IN REMOTE SENSING
- 12 EARTH OBSERVATIONS COMMERCIAL APPLICATIONS PROGRAM (EOCAP II) PROJECTS SELECTED
- WAKE SHIELD FACILITY UNDER DEVELOPMENT TO PROVIDE ON-ORBIT MATERIALS PROCESSING
- 5 PHARMACEUTICAL COMPANIES INVOLVED IN DEVELOPING PRODUCTS THROUGH PROTEIN CRYSTALLOGRAPHY RESEARCH
- 8 PROJECTS TO DEVELOP BIOPROCESSING PRODUCTS OR SERVICES UNDERWAY
- ZEOLITE PRODUCTS (ALUMINA SILICATES) SHOW INCREASING PROMISE FOR BUSINESS AND MEDICAL APPLICATIONS

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

KEY PROVISIONS
JOINT ENDEAVOR AGREEMENT

- **OBJECTIVE:** TO INDUCE THE PRIVATE CAPITAL INVESTMENT DECISION ON A SPACE-BASED VENTURE BY SIGNIFICANTLY REDUCING UPFRONT FINANCIAL AND TECHNICAL RISKS

- **MAJOR RESPONSIBILITIES OF PRIVATE ENTITY**
  - CONDUCT EXPERIMENTS IN LOW G AND/OR DEVELOP HARDWARE AT COMPANY EXPENSE
  - COMMERCIALIZE ANY PROMISING RESULTS DEVELOPED UNDER JEA

- **MAJOR NASA RESPONSIBILITIES**
  - PROVIDE SHUTTLE FLIGHTS AND OTHER LAUNCH RELATED STANDARD SERVICES AT NO CHARGE TO PRIVATE ENTITY
  - PROVIDE TECHNICAL SUPPORT AND USE OF OTHER NASA EQUIPMENT, FACILITIES ON A NONINTERFERENCE BASIS AT NO CHARGE TO PRIVATE ENTITY

CC-2012 10/28/88—TEM

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

SPACE SYSTEMS DEVELOPMENT AGREEMENT (SSDA)

- LAUNCH SERVICE AGREEMENT WITH SPECIAL PROVISIONS (E.G. DEFERRED PAYMENT SCHEDULE, EXCLUSIVITY)
- EARLY ENTRANTS IN NEW INDUSTRY
- INITIAL FLIGHTS OF A NEW SYSTEM CONTEMPLATED TO BEGIN GENERATING REVENUES DURING TERM OF AGREEMENT
- GENERALLY ASSOCIATED WITH DEVELOPMENT OF SPACE HARDWARE INFRASTRUCTURE
- POTENTIAL FOR SIGNIFICANT NATIONAL ECONOMIC OR OTHER BENEFITS

CC-2083 02/26/90—TEM

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

CURRENT COMMERCIAL FLIGHT EXPERIMENT REQUIREMENTS

BATTELLE
POLYMER COMPOSITES
PLASMA PARTICLE/FILM GENERATION
INVESTIGATIONS INTO POLYMER MEMBRANES PROCESSING
SOLUTION CRYSTAL GROWTH
FLOAT ZONE CRYSTAL GROWTH
ZEOLITE CRYSTAL GROWTH

CASE WESTERN
MATERIALS EXPOSURE - BASIC
MATERIALS EXPOSURE - APPLIED
MATERIALS EXPOSURE - ADVANCED

CLARKSON
LOW TEMPERATURE SOLIDIFICATION
DIRECTIONAL SOLIDIFICATION-CDTE
CHEMICAL VAPOR TRANSPORT OF CDTE
LIQUID ENCAPSULATED MELT ZONE
COMMERCIAL SOLUTION GROWTH FACILITY

COLORADO
GENERIC BIOPROCESSING APPARATUS
AUTONOMOUS BIOMEDICAL TEST APPARATUS
MICRO-ORGANISMIC REACTOR
CENTRIFUGAL FLUIDS MANAGEMENT
PLANT GROWTH APPARATUS
BIOSERVE MATERIALS DISPERSION APPARATUS

ERIM
GLOBAL TROSOPHERIC CARBON MONOXIDE MEASUREMENTS
AUTOMATED MICROGRAVITY MATERIALS PROCESSING
AUTONOMOUS RENDEZVOUS AND DOCKING

HOUSTON
MOLECULAR BEAM EPITAXY-SEMICONDUCTORS AND GaAs
MOLECULAR BEAM EPITAXY-SEMICONDUCTORS, GaAlAs AND GaInAs
MOLECULAR BEAM EPITAXY-SUPERCONDUCTORS AND GaAs
MOLECULAR BEAM EPITAXY-HIGH TEMP SUPERCONDUCTOR AND GaAlAs

OHIO/ITD
MAPSAT

PENN STATE
LIGHT STIMULUS
BONE DENSITOMETRY
EGG INCUBATOR
PHYSIOLOGICAL SYSTEMS EXPERIMENT
BIOMODULE
COMMERCIAL ELECTROPHORESIS PROGRAM IN SPACE

NASA
OFFICE OF COMMERCIAL PROGRAMS

CURRENT COMMERCIAL FLIGHT EXPERIMENT REQUIREMENTS (CONT.)

TENNESSEE
PROPULSION
MICROGRAVITY FLUID MANAGEMENT
SPACE APPLICATIONS OF INDUSTRIAL LASER SYSTEMS

TEXAS A&M
MICRO HEAT PIPE EVALUATION
MICROWAVE POWER TRANSMISSION-PHASE I
MICROWAVE POWER TRANSMISSION-PHASE II
FROZEN STARTUP OF A HEAT PIPE IN MICROGRAVITY

UAB
PROTEIN CRYSTALLIZATION FACILITY
PROTEIN CRYSTAL GROWTH
PROTOTYPE PROTEIN CRYSTAL GROWTH
THERMAL ENCLOSURE SYSTEM

UAH
NON-LINEAR OPTICAL MATERIALS
3-D MICROGRAVITY ACCELEROMETER
IMMISCIBLE POLYMERS
ORGANIC SEPARATION
ELECTRODEPOSITION
NUCLEAR TRACK DETECTORS
POLYMER FOAM
SPACE EXPERIMENT FACILITY
HIGH TEMPERATURE SUPERCONDUCTORS
SINTERED AND ALLOYED MATERIALS
MATERIALS DISPERSION APPARTUS
ATOMIC OXYGEN

VANDERBILT
CRYSTAL GROWTH OF ELECTRONIC MATERIALS
COMPUTATIONAL MODELING OF CASTING PROCESSES
SOLAR FURNACE SATELLITE

WISCONSIN
ASTROCULTURE

GODDARD SPACE FLIGHT CENTER
ROBOTIC MATERIALS PROCESSING SYSTEM

LANGLEY RESEARCH CENTER
GAS PERMEABLE POLYMER MATERIALS
MATERIALS IN DEVICES AS SUPERCONDUCTORS

3M (JEA)
POLYMER MORPHOLOGY
PHYSICAL VAPOR TRANSPORT OF ORGANIC SOLUTIONS
GELATION OF SOLS
POLYMERIZATION WITH LIGHT UNDER MICROGRAVITY

CURRENT COMMERCIAL FLIGHT EXPERIMENT REQUIREMENTS (CONT.)

BIOCRYST (SSDA)*
PROTEIN CRYSTAL GROWTH

ITA (SSDA)*
MATERIALS DISPERSION APPARATUS

BOEING (JEA)
CHEMICAL VAPOR TRANSPORT EXPERIMENT

ROCKWELL (JEA)
FLUIDS EXPERIMENT APPARATUS

ITA (JEA)
ITA STANDARDIZED EXPERIMENT MODULE

* IN NEGOTIATION

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

CURRENT TRANSPORTATION PLANNING
COMMERCIAL USE OF SPACE

	FISCAL YEAR								
	1991	1992	1993	1994	1995	1996	1997	1998	TOTAL
SHUTTLE EXPERIMENTS									
CARGO BAY/CAP	1	7	4	12	8	2	5	—	39
MIDDECK / SPACELAB	9	11	10	17	17	10	4	—	78
SPACEHAB EXPERIMENTS									
FLIGHTS (MODULE UTILIZATION)	—	—	0.8	1.6	1.6	—	—	—	4
PAYLOAD TESTS	—	—	16	32	29	—	—	—	77
EXPENDABLE LAUNCH VEHICLES (COMET)									
FLIGHTS	—	1	—	1	1	—	—	—	4
PAYLOAD TESTS	—	9	—	7	6	—	—	—	27
SOUNDING ROCKETS									
FLIGHTS	1	2	2	2	2	—	—	—	9
PAYLOAD TESTS	0	19	17	13	10	—	—	—	59
SPACE STATION									
FLIGHTS (UTILIZATION)	—	—	—	—	—	2	2	2	6
PAYLOAD TESTS	—	—	—	—	—	7	13	21	41
								TOTAL	321

CC-2624 8/1/91

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

CCDS EXPENDABLE LAUNCH VEHICLE PROGRAM

MISSION	1989	1990	1991	1992
CONSORT 1	3/29			
CONSORT 2*	11/15			
CONSORT 3		5/16		
JOUST 1*			6/18	
CONSORT 4			11/13	
JOUST 2				5/6
COMET 1				10/92

* UNSUCCESSFUL

CC-2743 8/2/91

COMMERCIAL MIDDECK AUGMENTATION MODULE (CMAM)

- OFFICE OF COMMERCIAL PROGRAMS WILL LEASE SPACEHAB SERVICES TO ACCOMMODATE ITS PAYLOAD FLIGHT REQUIREMENTS

- ON NOVEMBER 30, 1990, A CMAM CONTRACT WAS SIGNED FOR 200 MIDDECK LOCKER EQUIVALENTS OVER 6 FLIGHTS WITH SPACEHAB, INC.

- SPACEHAB IS A PRESSURIZED, ORBITER-BASED CARRIER DESIGNED TO AUGMENT THE ORBITER MIDDECK

- FIRST FLIGHT FOR SPACEHAB IS SCHEDULED FOR APRIL 1993

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

COMMERCIAL EXPERIMENT TRANSPORTER (COMET) PROGRAM

- COMET IS A COMMERCIALLY DEVELOPED SYSTEM FOR LAUNCHING AND RECOVERING COMMERCIAL SPACE-BORNE EXPERIMENTS

- LED BY THE CENTER FOR ADVANCED SPACE PROPULSION, UNIVERSITY OF TENNESSEE WITH SIX OTHERS CCDS's PROVIDING OVERSIGHT FOR COMET SYSTEMS

- COMET WILL BE CARRIED ALOFT BY AN EXPENDABLE LAUNCH VEHICLE AND CONTAIN BOTH AN ORBITING SERVICE MODULE AND A RECOVERY CAPABILITY

- EER TO PROVIDE THE LAUNCH VEHICLE AND SERVICES

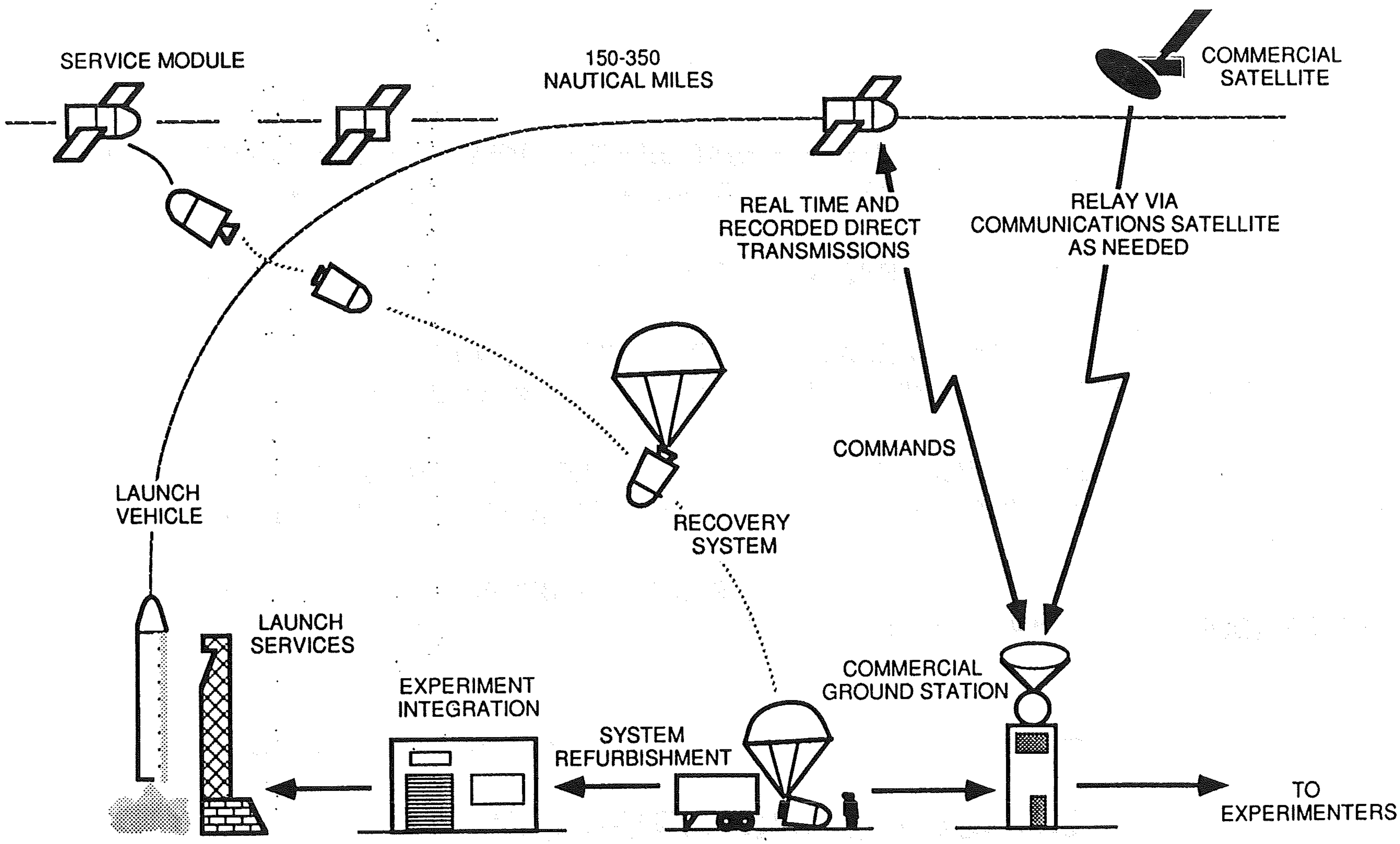
- SPACE INDUSTRIES, INC. TO PERFORM PAYLOAD INTEGRATION AND ORBITAL OPERATIONS; AND TO PROVIDE THE RECOVERY SYSTEM

- WESTINGHOUSE TO PROVIDE SYSTEMS ENGINEERING AND THE SERVICE MODULE

- LAUNCH OF COMET-1 SCHEDULED FOR SEPTEMBER 1992, TWO FOLLOW-ON FLIGHTS IN 1994 AND 1995

CP-4529 8/5/91

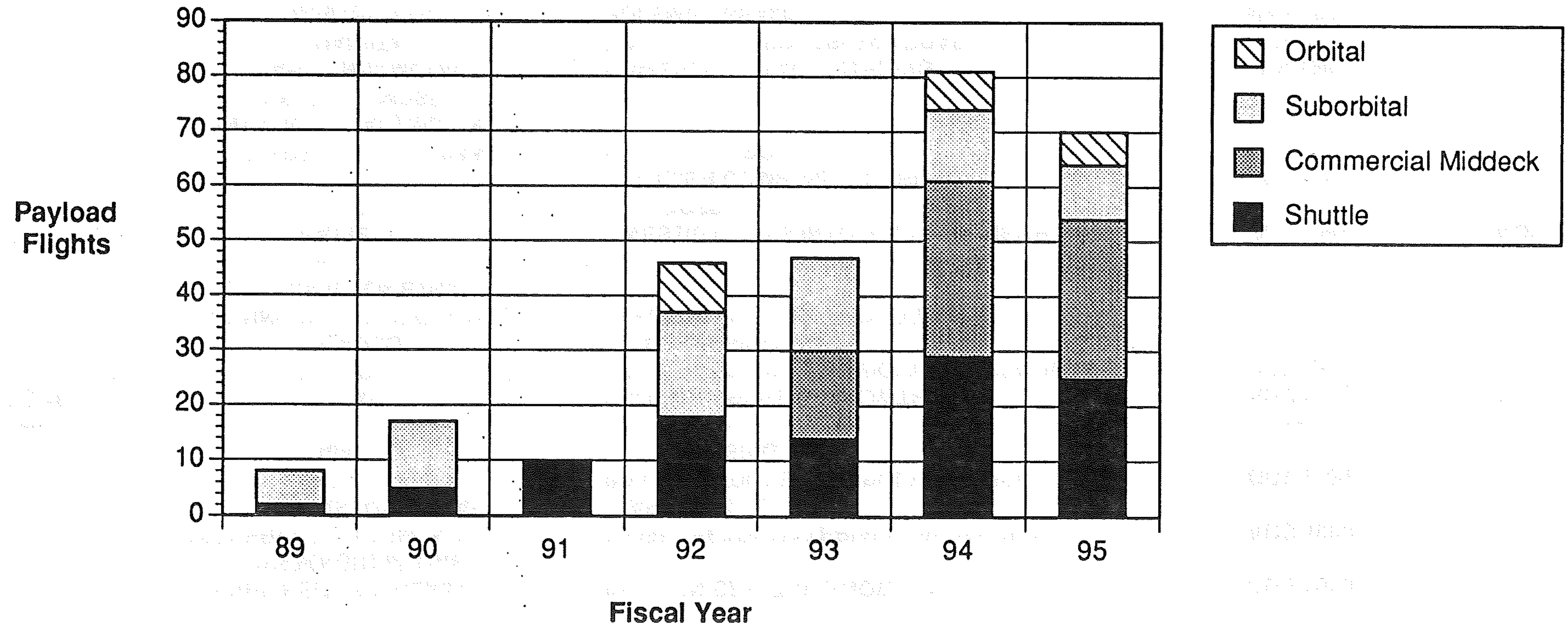
COMMERCIAL EXPERIMENT TRANSPORTER CONCEPT



CP-4513 8/2/90

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

OCP FLIGHT PROGRAM



141

CC- 2741 8/1/91

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

COMMERCIAL FLIGHT PROJECTION THROUGH FISCAL YEAR 1992

FLIGHT	SPONSOR	PAYLOAD	HARDWARE AVAILABILITY	LAUNCH DATE
STS-43	UNIVERSITY OF ALABAMA -BIRMINGHAM (UAB)	PROTEIN CRYSTAL GROWTH*	AUG 1988	AUG 1991
	BIOSERVE/INSTRUMENTATION TECH. ASSOCS. (ITA)	BIOSERVE/ITA MATERIALS DISPERSION APPARATUS*	AUG 1990	
	BATTELLE/ AMOCO	INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING*	OCT 1989	
STS-48	UAB	PROTEIN CRYSTAL GROWTH*	AUG 1988	SEP 1991
	BATTELLE/ AMOCO	INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING*	OCT 1989	
	JOHNSON SPACE CENTER (JSC)/AUTOMETRIC	ELECTRONIC STILL PHOTOGRAPHY - DTO*		
CONSORT-04	BATTELLE/ AMOCO	INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING*	OCT 1989	NOV 1991
		POLYMER COMPOSITE CURING*	APR 1990	
	UNIVERSITY OF ALABAMA -HUNTSVILLE (UAH)/MCDONNEL DOUGLAS (MDSSC)	ELECTRODEPOSITION*	FEB 1989	
	UAH/KENNAMETAL	POWERED METAL SINTERING*	FEB 1989	
	UAH/ITA	MATERIALS DISPERSION APPARATUS*	FEB 1989	
	UAH/THIOKOL	POLYMER BEAM*	MAY 1991	
	BIOSERVE	GENERIC BIOPROCESSING APPARATUS*	APR 1990	
	PENN STATE UNIV./GENENTECH	BIOMODULE*	OCT 1989	

* *ASSIGNED*
** *FLIGHT COMPLETED*
NOTE: SHUTTLE FLIGHT DATES ARE BASED ON MANIFEST PLANNING ON 6/28/91

CC-2313B (page 1 of 3) 8/2/91

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

COMMERCIAL FLIGHT PROJECTION THROUGH FISCAL YEAR 1992 (CONTINUED)

FLIGHT	SPONSOR	PAYLOAD	HARDWARE AVAILABILITY	LAUNCH DATE
STS-42	BATTELLE/ AMOCO	INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING*	OCT 1989	JAN 1992
	UAB	PROTEIN CRYSTAL GROWTH *	AUG 1988	
	3M	GELATION OF SOLS*	JAN 1991	
	JSC/AUTOMETRIC	ELECTRONIC STILL PHOTOGRAPHY - DTO*		
STS-45	BATTELLE/AMOCO	INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING*	OCT 1989	MAR 1992
STS-49	BOEING	CRYSTALS BY VAPOR TRANSPORT EXPERIMENT *	OCT 1991	APR 1992
	UAB	PROTEIN CRYSTAL GROWTH*	SEPT 1991	
JOUST-02	BATTELLE/AMOCO	INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING*	OCT 1989	MAY 1992
		POLYMER COMPOSITE CURING*	APR 1990	
	UAH/MDSSC	ELECTRODEPOSITION*	FEB 1989	
	UAH/KENNAMETAL	POWERED METAL SINTERING*	FEB 1989	
	UAH/THIOKOL	POLYMER FOAM*	FEB 1989	
		THIOKOL THIN FILMS*	FEB 1989	
	BIOSERVE	GENERIC BIOPROCESSING APPARATUS*	APR 1990	
	PENN. STATE UNIV/GENENTECH	BIOMODULE*	OCT 1989	
	UAH/(ITA)	MATERIALS DISPERSION APPARATUS*	FEB 1989	
STS-50	BATTELLE/AMOCO	ZEOLITE CRYSTAL GROWTH*	DEC 1991	JUNE 1992
		INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING	OCT 1989	
	UAB	PROTEIN CRYSTAL GROWTH*	AUG 1988	
	WISCONSIN	ASTROCULTURE*	DEC 1991	
	BIOSERVE	GENERIC BIOPROCESSING APPARATUS*	SEPT 1991	
	UAH/TELEDYNE BROWN	CONCAP-4	DEC 1991	

* *ASSIGNED*
** *FLIGHT COMPLETED*
NOTE: SHUTTLE FLIGHT DATES ARE BASED ON MANIFEST PLANNING ON 6/28/91

CC-2313B (page 2 of 3) 8/2/91

NASA
OFFICE OF COMMERCIAL PROGRAMS

COMMERCIAL FLIGHT PROJECTION THROUGH FISCAL YEAR 1992 (CONTINUED)

FLIGHT	SPONSOR	PAYLOAD	HARDWARE AVAILABILITY	LAUNCH DATE
STS-46	CASE WESTERN	LIMITED DURATION CANDIDATE MATERIALS EXPOSURE (3)*	DEC 1991	JUN 1992
	UAH/LOS ALAMOS NATL LABS	CONCAP-2*	DEC 1991	
	UAH/TELEDYNE BROWN	CONCAP-3*	DEC 1991	
STS-47	UAB	PROTEIN CRYSTAL GROWTH*	AUG 1988	AUG 1992
STS-52	UAB	PROTEIN CRYSTAL GROWTH	AUG 1988	SEP 1992
	PENN STATE UNIV/GENENTECH	PHYSIOLOGICAL SYSTEMS EXPERIMENT	APR 1990	
	UAH/ITA	MATERIALS DISPERSION APPARATUS	AUG 1990	
	BIOSERVE	GENERIC BIOPROCESSING APPARATUS	SEPT 1991	
	BATELLE/AMOCO	INVESTIGATIONS INTO POLYMER MEMBRANE PROCESSING	OCT 1989	
	UAH/LOS ALAMOS NATL LABS	CONCAP-2	DEC 1991	
	CASE WESTERN	LIMITED DURATION CANDIDATE MATERIALS EXPOSURE	DEC 1991	
COMET-01	BIOSERVE	AUTONOMOUS BIOMEDICAL TEST APPARATUS	JUNE 1991	SEPT 1992
		PLANT GROWTH APPARATUS		
	UAH/ITA	MATERIALS DISPERSION APPARATUS		
	UAH	NON-LINEAR OPTICAL MATERIALS		
		ATOMIC OXYGEN		
	PENN STATE	BIOMODULE		
	CASE WESTERN	MATERIALS LABORATORY-2		
	UAB	PROTEIN CRYSTAL GROWTH		
	ERIM	AUTONOMOUS RENDEZVOUS DOCKING		

* *ASSIGNED*
** *FLIGHT COMPLETED*
NOTE: SHUTTLE FLIGHT DATES ARE BASED ON MANIFEST PLANNING ON 6/28/91

CC-2313B (page 3 of 3) 8/2/91

SPACE STATION FREEDOM PAYLOAD SPONSORS

- JAPAN – NASDA
- EUROPEAN SPACE AGENCY – ESA
- CANADA – CSA
- UNITED STATES – NASA
  - OFFICE OF COMMERCIAL PROGRAMS - OCP (CODE C)
  - OFFICE OF SPACE SCIENCE AND APPLICATIONS - OSSA (CODE S)
  - OFFICE OF AERONAUTICS, EXPLORATION AND TECHNOLOGY - OAET (CODE R)
  - OFFICE OF SPACE FLIGHT - OSF (CODE M)

NASA
OFFICE OF COMMERCIAL PROGRAMS

COMMERCIAL SPACE STATION FREEDOM PLANNING TEAM

PURPOSE

- PLAN FOR COMMERCIAL UTILIZATION OF SPACE STATION FREEDOM

- IDENTIFY COMMERCIAL SPACE STATION FREEDOM PAYLOAD TRAFFIC MODEL

- DEVELOP OFFICE OF COMMERCIAL PROGRAMS SPACE STATION FREEDOM DATA BASE

- SUPPORT THE OFFICE OF SPACE STATION USER ACTIVITIES

CC-2053 8/2/90

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

COMMERCIAL SPACE STATION FREEDOM PLANNING TEAM

COMMERCIAL SPACE STATION PLANNING (NASA HEADQUARTERS)

MATERIALS PROCESSING (MSFC) (TELEDYNE BROWN)

BATTELLE
BOEING
CLARKSON
U. HOUSTON
MRA
ROCKWELL INTN.
3M CORP
UAB
UAH
VANDERBILT

BIOTECHNOLOGY (ARC) (LOCKHEED)

U. COLORADO
PENN STATE
WISCONSIN
UAB

REMOTE SENSING (SSC) (LOCKHEED)

ITD
OHIO STATE

SYSTEMS AND SERVICES (MSFC)

AUBURN
CASE WESTERN
SPARC
TEXAS A&M
CASP
WISCONSIN
ITA

CC - 2748 8/5/91

NASA
OFFICE OF
COMMERCIAL
PROGRAMS

CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE (CCDS) EXPERIENCE

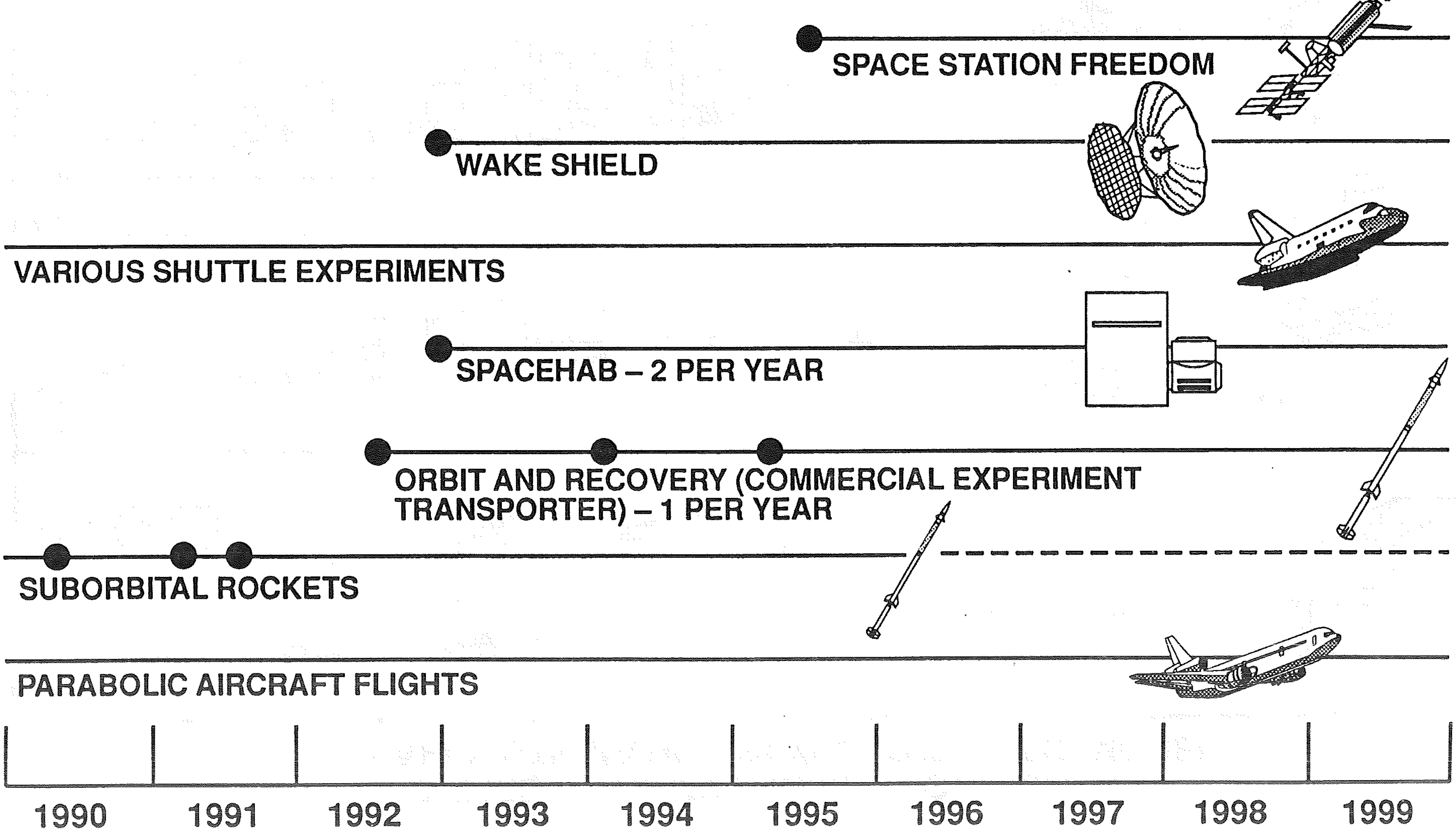
- FLIGHT EXPERIENCE ON MANNED AND UNMANNED VEHICLES
  - KC-135, SOUNDING ROCKETS, SHUTTLE (MIDDECK, COMMERCIAL MIDDECK AUGMENTATION MODULE (CMAM), PAYLOAD BAY), WAKE SHIELD, COMMERCIAL EXPERIMENT TRANSPORTER (COMET)
- HARDWARE DEVELOPMENT EXPERIENCE
- RIGOROUS PRE-STATION FLIGHT PLAN WITH COMMERCIAL PAYLOADS
- SAFETY AND INTEGRATION EXPERIENCE WITH NASA FIELD CENTERS
- DEMONSTRATED ABILITY TO BUILD LOW-COST, HIGH-QUALITY HARDWARE

CONCLUSION: CCDS'S SHOULD BE ABLE TO DOVETAIL NICELY WITH SPACE STATION FREEDOM CAPABILITIES

CC-2639 4/25/91

COMMERCIAL ROLES OF SPACE STATION FREEDOM

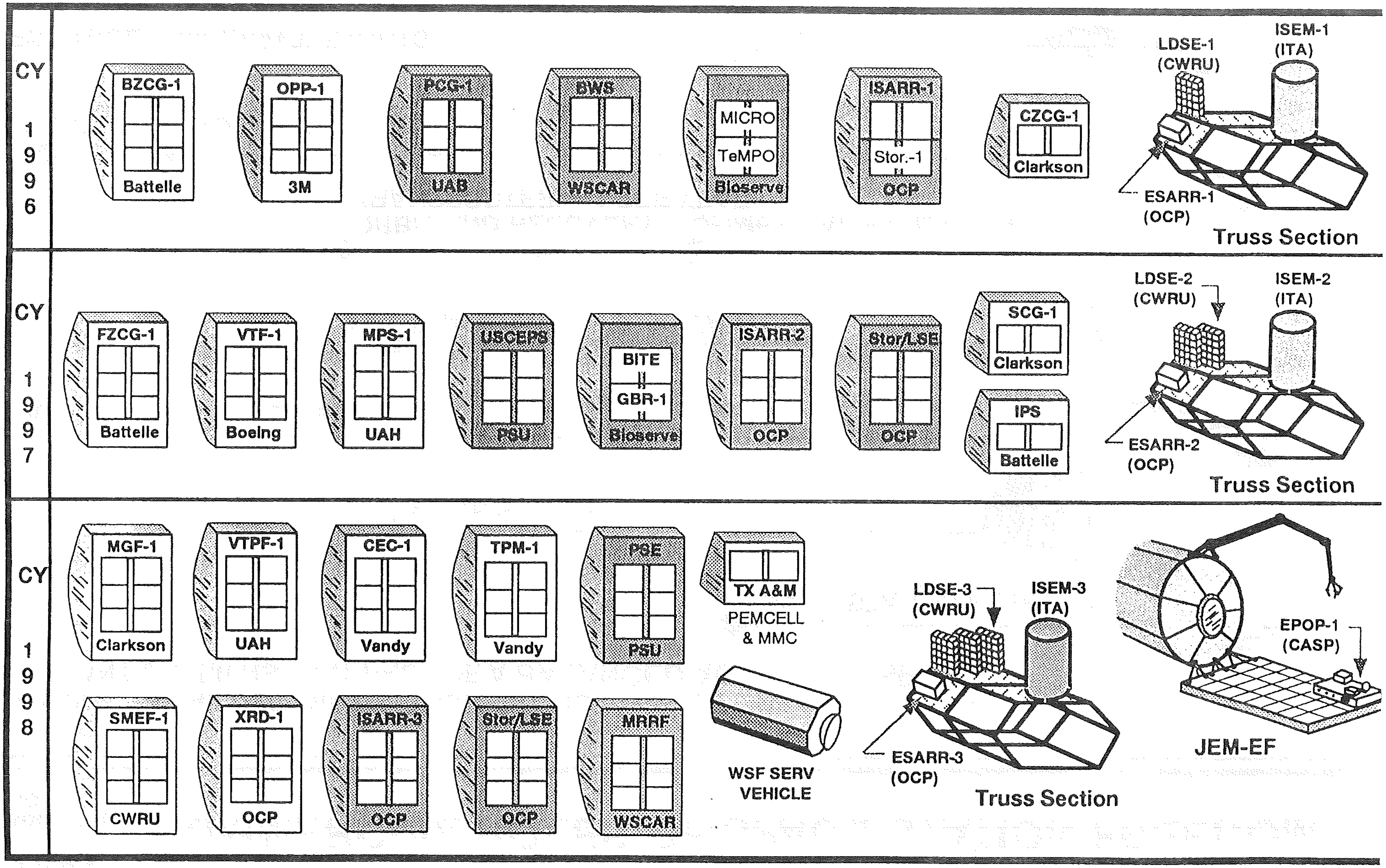
FOR COMMERCIAL PROGRAMS, SPACE STATION WILL BE ONE OF THE MOST IMPORTANT CARRIERS THAT PROVIDE A BALANCED ACCESS TO SPACE



CC-2718 6/12/91

DRAFT

OFFICE OF COMMERCIAL PROGRAMS SSF EARLY UTILIZATION PAYLOAD TRAFFIC MODEL



Note: ISEM, ESARR, and ISARR return after one increment. All other payload racks are cumulative. Total: 25 racks

Materials Discipline | Life Sciences/Biotechnology Discipline | Robotics Discipline | Storage/LSE | TBD

July 31,1991

OFFICE OF
COMMERCIAL
PROGRAMS

OFFICE OF COMMERCIAL PROGRAMS
SPACE STATION FREEDOM PAYLOADS

PAYLOAD	ACRONYM	PAYLOAD
INTERNAL PAYLOADS		
3M CORPORATION	OPP	ORGANIC AND POLYMER PROCESSING
BATTELLE	FZCG	FLOAT ZONE CRYSTAL GROWTH
BATTELLE	BZCG	BATTELLE ZEOLITE CRYSTAL GROWTH
BATTELLE	IPS	INVESTIGATIONS OF POLYMER STRUCTURES
BIOSERVE	MICRO	MODULE FOR INTEGRATED CELL RESEARCH IN ORBIT
BIOSERVE	TEMPO	TEST MODULE FOR PLANTS/ORGANICS
BIOSERVE	BITE	BIOMEDICAL ISOMORPHISMS TEST EQUIPMENT
BIOSERVE	GBR	GENERIC BIOPROCESSING RACK
BOEING	VTF	VAPOR TRANSPORT FURNACE
CLARKSON	CZCG	CLARKSON ZEOLITE CRYSTAL GROWTH
CLARKSON	SCG	SOLUTION CRYSTAL GROWTH
CLARKSON	MGF	MELT GROWTH FURNACE
CASE WESTERN	SMEF	SPACE MATERIALS EVALUATION FACILITY
OCP	XRD	X-RAY DIFFRACTION
PENN STATE	USCEPS	U.S. COMMERCIAL ELECTROPHORESIS
PENN STATE	PSE	PHYSIOLOGICAL SYSTEMS EXPERIMENTS
TEXAS A&M	PEMCELL	PROTON EXCHANGE MEMBRANE FUEL CELL
TEXAS A&M	MMC	METAL MATRIX COMPOSITES
UA/BIRMINGHAM	PCG	PROTEIN CRYSTAL GROWTH
UA/HUNTSVILLE	MPS	MATERIALS PROCESSING SYSTEM
UA/HUNTSVILLE	VTPF	VAPOR TRANSPORT PROCESSING FURNACE
VANDERBILT	CEC	CONVECTIVE EFFECTS IN CASTING
VANDERBILT	TPM	THERMOPHYSICAL PROPERTIES MEASUREMENTS
WISCONSIN	BWS	BIOREGENERATIVE WATER SYSTEM
INTERNAL PAYLOADS		
LDSE	CASE WESTERN	LONG DURATION SPACE EXPERIMENTS
ISEM	ITA	ITA STANDARDIZED EXPERIMENT MODULE
EPOP	U/TENNESSEE/CASP	ELECTRIC PROPULSION ORBITAL PLATFORM
WSFSV	U/HOUSTON	WAKESHIELD FACILITY SERVICE VEHICLE

CC-2746 8/2/91

SPACE STATION FREEDOM PAYLOAD HERITAGE

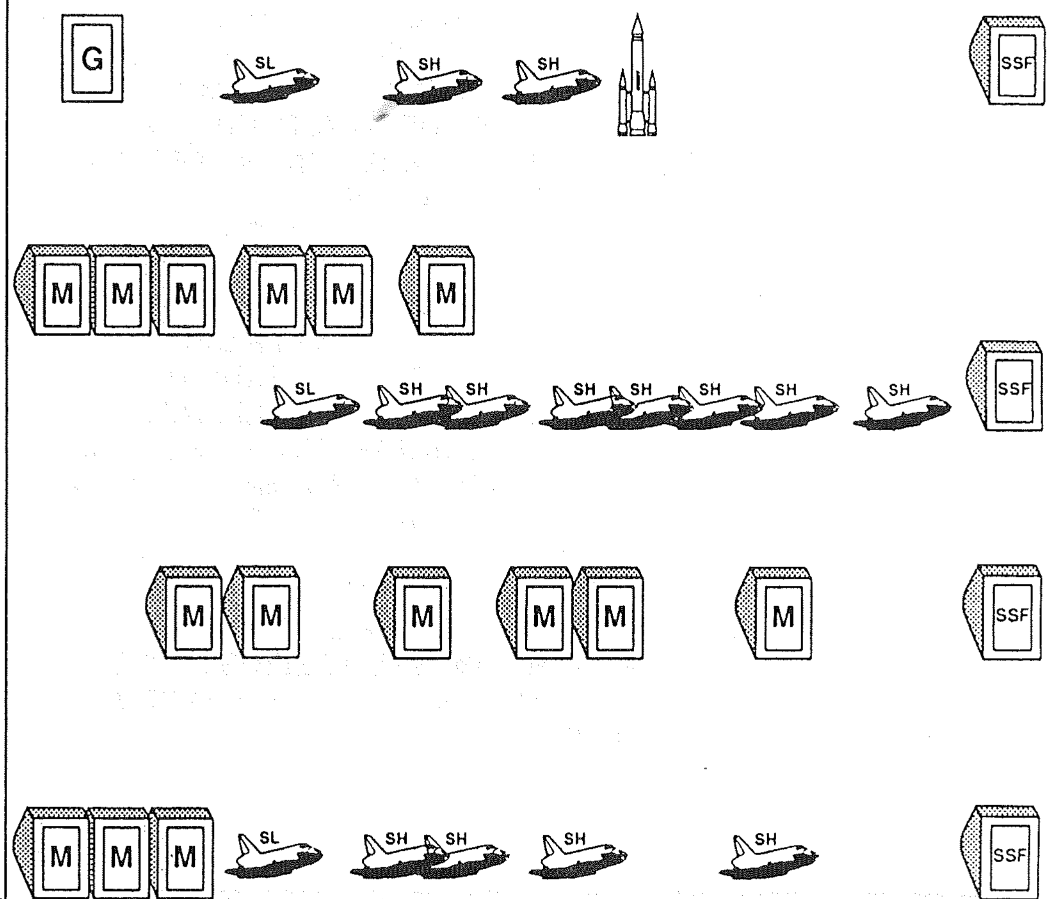
SPACE STATION FREEDOM PAYLOAD	PRECURSOR FLIGHTS 1991	1992	1993	1994	1995	1996

Zeolite Crystal Growth (ZCG)
Battelle
- Applications: Kidney dialysis, radioactive waste cleanup, petroleum processing
- Affiliates: Amoco Chemical Co., DuPont, Intek, Teledyne Brown

Protein Crystal Growth (PCG)
UAB
- Applications: Human gamma-interferon, isocitrate lyase
- Affiliates: Schering-Plough, Burroughs Wellcome, DuPont, Genentech, Vertex, SmithKline & French, Upjohn, Eli Lilly, Eastman Kodak, Biocryst, Space Industries, Inc.

Bioregenerative Water System (BWS)
WSCAR
- Applications: Controlled plant growth environments, water regeneration for space application
- Affiliates: Quantum Devices, Inc., Phytofarms of America, Inc,. Automated Agriculture Assoc., Inc.

Module for Integrated Cell Research In Orbit (MICRO)
Bioserve
- Applications: Membrane formation, crystal growth, cell cultures, organism growth
- Affiliates: Alaza, Ball, Boeing, Central Biomedia, DuPont, Omni Data, Juvenile Diabetes Foundation



Legend: Middeck; SpaceHab/SpaceLab; Space Station Freedom; Comet; Sounding Rocket; Gas Can

CC-2664 (page 1) 5/24/91

ADVANTAGES OF SPACE STATION FREEDOM FOR COMMERCIAL PAYLOADS

- ~ 27 user racks available for U.S. payloads at PMC
- Adequate power levels to support commercial payloads
- Adequate G-levels to support commercial payloads
- Payloads can operate on Space Station during untended periods - free flyer environment
- Crew presence during Shuttle visits for sample changeout, payload deployment, and/or repair
- Potential of external attached payloads pre-integrated into truss structure for long-duration operations

SPACE STATION FREEDOM EVOLUTION

COMMERCIAL INFRASTRUCTURE CONSIDERATIONS

- Lab Support Equipment Development (X-Ray Diffraction, Etc.)
- Commercial Rack/Drawer Capability
- Spacehab Physical Integration and Use as a Logistics Carrier
- Wakeshield as SSF Serviced Free Flyer
- Comet Service Modules as SSF Serviced Free Flyers
- Comet Derived Maneuvering Service Vehicle (MSV)
- Comet Recovery System
- Ground Operations Capability for Comet and Wakeshield

CC-2668 8/5/91

SUMMARY

SPACE STATION FREEDOM WILL PROVIDE THE IMPORTANT LONG DURATION LABORATORY COMPONENT WHICH WILL ENABLE COMMERCIAL TECHNOLOGIES TO TRANSITION TO NEW SPACE BASED MARKETS

CC-2747 8/5/91

TECHNOLOGY DEVELOPMENT ON EVOLUTIONARY SPACE STATION

SPACE STATION EVOLUTION SYMPOSIUM

Dr. Judith H. Ambrus
Assistant Director for SpaceTechnology
August 6, 1991

OAET

SPACE R&T MISSION STATEMENT

OAET

OAET SHALL PROVIDE TECHNOLOGY FOR FUTURE CIVIL SPACE MISSIONS AND PROVIDE A BASE OF RESEARCH AND TECHNOLOGY CAPABILITIES TO SERVE ALL NATIONAL SPACE GOALS

- ***IDENTIFY, DEVELOP, VALIDATE AND TRANSFER TECHNOLOGY TO:***
  - **INCREASE MISSION SAFETY AND RELIABILITY**
  - **REDUCE PROGRAM DEVELOPMENT AND OPERATIONS COST**
  - **ENHANCE MISSION PERFORMANCE**
  - **ENABLE NEW MISSIONS**
- ***PROVIDE THE CAPABILITY TO:***
  - **ADVANCE TECHNOLOGY IN CRITICAL DISCIPLINES**
  - **RESPOND TO UNANTICIPATED MISSION NEEDS**

LBF4194B

NASA ACTION PLAN

ADVISORY COMMITTEE ON THE FUTURE OF THE U.S. SPACE PROGRAM

RECOMMENDATION 8:

That NASA, in concert with the Office of Management and Budget and appropriate Congressional committees, establish an augmented and reasonably stable share of NASA's total budget that is allocated to advanced technology development. A two- to three-fold enhancement of the current modest budget seems not unreasonable.

In addition, we recommend that an agency-wide technology plan be developed with inputs from the Associate Administrators responsible for the major development programs, and that NASA utilize an expert, outside review process, managed from headquarters, to assist in the allocation of technology funds.

NASA ADMINISTRATOR ACTION:

Codes R/M/S/O/AA for Exploration (Code R lead): Provide an integrated agency-wide technology development plan (using the FY 91 appropriated budget as the base, and based on two- and three-fold budget increase); due at macro level 6/91; refined plan 11/91

RECOMMENDATION 7:

That Technology Be Pursued Which Will Enable A Permanent, Possibly Man-Tended Outpost To Be Established On The Moon For The Purposes of Exploration And For The Development Of The Experience Base Required For The Eventual Human Exploration Of Mars.

That NASA Should Initiate Studies Of Robotic Precursor Missions and Lunar Outposts.

NASA ADMINISTRATOR ACTION:

Include Technology Aspects in The Technology Planning Action Responding to Recommendation 8

MARCH 6, 1991
JCM-7268

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

RESEARCH & TECHNOLOGY STRATEGY

OAET

FLIGHT PROGRAMS FORECAST

• 5-YEAR FORECAST INCLUDES

'93 THRU '97: LIMITED NEW STARTS	COMPLETION OF INITIAL SSF SOME SHUTTLE IMPROVEMENTS INITIAL EOS & EOSDIS SELECTED SPACE SCIENCE STARTS NLS DEVELOPMENT INITIAL SEI ARCHITECTURE SELECTION EVOLVING GEO COMMERCIAL COMMSATS MINOR UPGRADES OF COMMERCIAL ELVS

• 10-YEAR FORECAST INCLUDES

'98 THRU '03: MULTIPLE NEW STARTS TO BE LAUNCHED IN 2003 THRU 2010	SSF EVOLUTION/INFRASTRUCTURE FINAL SHUTTLE ENHANCEMENTS ADVANCED LEO EOS PLATFORMS/FULL EOSDIS MULTIPLE SPACE SCIENCE STARTS NLS OPERATIONS/EVOLUTION EVOLVING LAUNCH/OPERATIONS FACILITIES INITIAL SEI/LUNAR OUTPOST START DSN EVOLUTION (KA-BAND COMMUNICATIONS) NEW GEO COMMERCIAL COMMSATS NEW COMMERCIAL ELVS

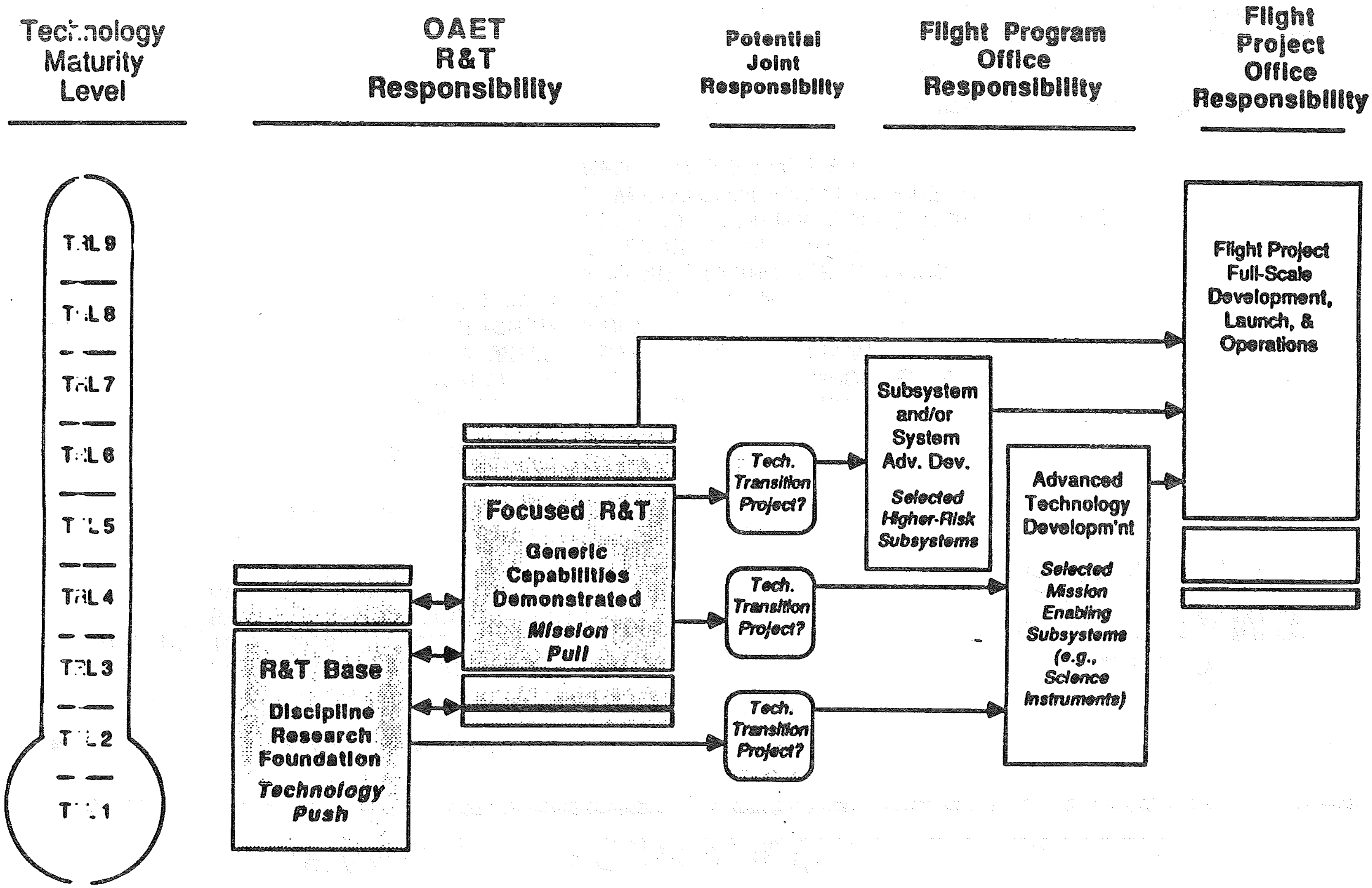
• 20-YEAR FORECAST INCLUDES

'04 THRU '11 MULTIPLE OPTIONS FOR NEW STARTS TO BE LAUNCHED IN 2009 THRU 2020	SSF-MARS EVOLUTION BEGINNING OF AMLS/PLS DEVELOPMENT MULTIPLE SPACE SCIENCE STARTS DSN EVOLUTION (OPTICAL COMM) INITIAL MARS HLLV DEVELOPMENT EVOLVING LUNAR SYSTEMS MARS SEI ARCHITECTURE CHOSEN LARGE GEO COMMSATS NEW COMMERCIAL ELVS

MAY 10, 1991
JCM-7692

NASA TECHNOLOGY MATURATION STRATEGY

OAET



APRIL 15, 1991
JCM-7079b

OSF Technology Requirements Evaluation

Technology Areas

Program Unique Technologies

1. Vehicle Health Management
2. Advanced Turbomachinery Components and Models
3. Combustion Devices
4. Advanced Heat Rejection Devices
5. Water Recovery and Management
6. High Efficiency Space Power Systems
7. Advanced Extravehicular Mobility Unit Technologies
8. Electromechanical Control Systems/Electrical Actuation
9. Crew Training Systems
10. Characterization of Al-Li Alloys
11. Cryogenic Supply, Storage, and Handling
12. Thermal Protection Systems for High Temperature Applications
13. Robotic Technologies
14. Orbital Debris Protection
15. Guidance, Navigation and Control
16. Advanced Avionics Architectures

Industry Driven Technologies

- Signal Transmission and Reception
- Advanced Avionics Software
- Video Technologies
- Environmentally Safe Cleaning Solvents, Refrigerants and Foams
- Non-Destructive Evaluation

Figure 3-1

EXTERNAL TECHNOLOGY PERSPECTIVES SUMMARY

OAET

SPACE SCIENCE

Precision Space Structures and Pointing Accuracy

PLANETARY SURFACE EXPLORATION

Regnerative Life Support Systems
Radiation Protection for Long Missions
Utilization of In Situ Materials/Propellants
Artificial Intelligence Techniques
Robotic & Microrobotic Systems
Advanced EMUs
Surface Rover Technologies (Pressurized and Unpressurized)
Nuclear Electric Power
High-Efficiency Lunar Radiators & Thermal Energy Storage
Power Beaming
Human Health Maintenance
Reduced Gravity Countermeasures/Artificial Gravity
Bioprocess-Grade Fluid Management Systems

SPACE PLATFORMS

Composite Lightweight Structures
Micrometeoroid and Debris Protection
Long-Life Structures and Mechanisms
Regnerative Life Support Systems
Advanced EMUs
Expanded Atomic Oxygen Database
High-Efficiency, Radiation-Resistant, Lightweight PV Arrays
High-Efficiency Power Processing Units
Lightweight Batteries

TRANSPORTATION

Economical Launch Systems (Manned and Unmanned)
Software Productivity Enhancers
Integrated Vehicle Health Monitoring and Maintenance
Advanced Cryogenic (Oxygen/Hydrogen) Engines
Fault-Tolerant Advanced Avionics with Open Architectures
High-Performance/Composite Lightweight Structures
Long-Life Structures and Mechanisms
High-Performance, Storable Space Thrusters
High-Power Electric Propulsion
Nuclear Thermal Propulsion for Manned Interplanetary Missions
Cryogenics Long-Duration Storage and Management
Gun-Type Launch Systems
Aerobraking (Thermal Protection Systems)
Integrated RCS/Auxiliary Propulsion
Lightweight, Fuel-Efficient Airbreather Propulsion Systems

OPERATIONS

Data Management System Architecture and Software
Systems Integration technologies (Software, etc.)
Artificial Intelligence Techniques
Safe Robotic Systems
Advanced Communications (e.g., Laser &
Millimeter Wave Technology)

JUNE 24, 1991
JCM-7660d

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

WORK BREAKDOWN STRUCTURE

OAET

SPACE RESEARCH & TECHNOLOGY

RESEARCH & TECHNOLOGY BASE

DISCIPLINE RESEARCH

Aerothermodynamics
Space Energy Conversion
Propulsion
Materials & Structures
Information and Controls
Human Support
Adv. Communications

UNIVERSITY PROGRAMS

SPACE FLIGHT R&T

Flight Experiment Studies
IN-STEP

SYSTEMS ANALYSIS

CIVIL SPACE TECHNOLOGY INITIATIVE

SPACE SCIENCE TECHNOLOGY

Science Sensing
Observatory Systems
Science Information
In Situ Science
Technology Flight Expts.

PLANETARY SURFACE EXPLORATION TECHNOLOGY

Surface Systems
Human Support
Technology Flight Expts.

TRANSPORTATION TECHNOLOGY

ETO Transportation
Space Transportation
Technology Flight Expts.

SPACE PLATFORMS TECHNOLOGY

Earth-Orbiting Platforms
Space Stations
Deep-Space Platforms
Technology Flight Expts.

OPERATIONS TECHNOLOGY

Automation & Robotics
Infrastructure Operations
Info. & Communciations
Technology Flight Expts.

LBF40353
(JCM-7650a)

INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

Critical User Requirements/Strategic Plan Element Categorization

OAET

	HIGHEST PRIORITY ◊◊◊			2nd-HIGHEST PRIORITY ◊◊			3rd-HIGHEST PRIORITY ◊		
Space Science Technology	Submillimeter Sensing	Direct Detectors Sensor Electronics	Active µwave Sensing Laser Sensing	Sample Acq., Analysis & Preservation	Passive Microwave Sensing	----	Optoelectrnics Sensing & Processing	Probes and Penetrators	----
	Cooler and Cryogenics	Microprecision CSI	Telescope Optical Systems	Data Archiving and Retrieval	Data Visualization	----	Precision Instrument Pointing	Sensor Optical Systems	----
Planetary Surface Exploration Technology	Radiation Protection	Regenerative Life Support (Phys-Chem.)	Space Nuclear Power (SP-100)	High Capacity Power	Planetary Rovers	Surface Habitats and Construction	Exploration Human Factors	----	Artifical Gravity
	----	----	Extravehicular Activity Systems	Surface Solar Power and Thermal Mgt.	In Situ Resource Utilization	Laser-Electric Power Beaming	Medical Support Systems	----	----
Transportation Technology	ETO Propulsion	Aeroassist Flight Expt Nuclear Thermal Propulsion	Aeroassist/ Aerobraking	Transfer Vehicle Avionics	ETO Vehicle Avionics	ETO Vehicle Structures & Materials	Autonomous Rendezvous & Docking	COHE	Auxiliary Propulsion
	Cryogenic Fluid Systems	Adv. Cryo. Engines	Low-Cost Commercial ETO XPort	Nuclear Electric Propulsion	CONE	SEPS TFE	Autonomous Landing	TV Structures and Cryo Tankage	HEAb
Space Platforms Technology	Platform Structures & Dynamics	Platform Power and Thermal Mgt.	Zero-G Life Support	Platform Materials & Environ. Effects	Station-Keeping Propulsion	----	Spacecraft On-Board Propulsion	Earth-Orbiting Platform Controls	Advanced Refrigerator Systems
	----	----	Zero-G Advanced EMU	Platform NDE-NDI	Deep-Space Power and Thermal	----	Spacecraft GN&C	Debris Mapping Experiment	----
Operations Technology	Space Data Systems	High-Rate Comm.	Artificial Intelligence	Ground Data Systems	Optical Comm Flight Expt Navigation & Guidance	Flight Control and Operations	Space Assembly & Construction	Space Processing & Servicing	Photonics Data Systems
	----	CommSat Communicat'ns	TeleRobotics	FTS DTF-1	Operator Syst./Training	CommSat Communicat'ns Flight Expts	----	Ground Test and Processing	----

LBF40343
(JCM-6800f)

TECHNOLOGY FLIGHT EXPERIMENTS

OAET

PURPOSE

- IN-SPACE EXPERIMENTS HAVE ALWAYS BEEN PART OF OAET'S PROGRAM
  - TO OBTAIN DATA THAT CAN NOT BEEN ACQUIRED ON THE GROUND
  - TO DEMONSTRATE FEASIBILITY OF CERTAIN ADVANCED TECHNOLOGIES

- CONDUCTING TECHNOLOGY EXPERIMENTS IN SPACE IS A VALUABLE AND COST EFFECTIVE WAY TO INTRODUCE ADVANCED TECHNOLOGIES INTO FLIGHT PROGRAMS

- UTILIZING THE SHUTTLE HAS DEMONSTRATED THE FEASIBILITY AND TIMELY BENEFITS OF CONDUCTING HANDS-ON EXPERIMENTS IN SPACE

- SPACE STATION FREEDOM WILL BE A PERMANENT LABORATORY IN SPACE THAT WILL PROVIDE THE LOGICAL AND EVOLUTIONARY EXTENSION OF GROUND BASED R&T

TECHNOLOGY FLIGHT EXPERIMENTS

OAET

TECHNOLOGY CATEGORIES

- SPACE STRUCTURES
  - ASSEMBLY, 0N-ORBIT NDE, REPAIR
  - DYNAMICS
- FLUID MANAGEMENT & PROPULSION
  - STORABLE AND CRYOGENIC
- POWER SYSTEMS & THERMAL MANAGEMENT
  - SOLAR CELLS, ENERGY STORAGE
  - TWO PHASE THERMAL MANAGEMENT DEVICES
- HUMANS IN SPACE
  - ENVIRONMENTAL CONTROL AND LIFE SUPPORT
  - HEALTH MAINTENANCE DEVICES
- SENSORS & INFORMATION SYSTEMS
- AUTOMATION AND ROBOTICS
- SPACE ENVIRONMENTAL EFFECTS
  - PLASMA, EMI, VIBROACUSTICS, MICROGRAVITY
  - MATERIALS

TECHNOLOGY FLIGHT EXPERIMENTS

OAET

SSF UTILIZATION PLANNING

- SSF FLIGHT EXPERIMENTS TRAFFIC MODEL

  - WITH COLLABORATION OF PIs OF CURRENT FLIGHT EXPERIMENT S
  - BALANCED BY TECHNOLOGY CATEGORY
  - USER NEED OF TECHNOLOGIES
  - SSF CAPABILITIES
  - OTHER SSF USER INTERACTIONS
  - UTILIZATION FLIGHT SEQUENCE

- REPRESENTS BEST ESTIMATES OF RESOURCE ENVELOPES

- EXPERIMENT SELECTION BY AO AND ESTABLISHED PROCEDURES

- EXTENT OF UTILIZATION DEPENDENT ON BUDGET

TECHNOLOGY FLIGHT EXPERIMENTS

OAET

JOINT PLANNING WITH DOD

170

- OAET HAS LONG STANDING TECHNOLOGY COORDINATION EFFORT WITH AIR FORCE THROUGH SPACE TECHNOLOGY INTERDEPENCY GROUP (STIG)

- IN 1990 THE STEERING GROUP AUTHORIZED FORMATION OF NEW COMMITTEE IN SPACE FLIGHT EXPERIMENTS

  - TO EXCHANGE DATA ON ON-GOING FLIGHT EXPERIMENTS
  - TO MAXIMIZE UTILIZATION OF RESOURCES
  - TO SHARE INFORMATION ON FLIGHT OPPORTUNITIES
  - TO JOINTLY PLAN FOR THE FUTURE

- THE COORDINATION HAS NOW BEEN EXPANDED TO INCLUDE THE ARMY AND NAVY

- OAET HAS AGREED TO REPRESENT THE POTENTIAL SSF USERS FROM DOD

  - TO TRANSMIT REQUIREMENTS
  - TO SHARE SSF RESOURCES

TECHNOLOGY FLIGHT EXPERIMENTS

OAET

INDUSTRY AND UNIVERSITY PARTICIPATION

- **SPACE TECHNOLOGY DEVELOPMENT IS AN ISSUE OF NATIONAL COMPETITIVENESS**

  - INDUSTRY PARTICIPATES THROUGH THE IR&D PROCESS

  - UNIVERSITIES ARE THE MAJOR RESOURCE FOR INNOVATIVE TECHNOLOGIES AND TRAINED PROFESSIONALS

- **PLANS ARE UNDERWAY TO FORMALIZE THE INTERACTIONS WHICH WILL LEAD TO ACTIVE PARTICIPATION IN TECHNOLOGY FLIGHT EXPERIMENTS PROGRAM**

PROPOSED STATION PAYLOADS BY THRUST

SCIENCE	PLATFORMS	TRANSPORTATION
MANNED OBSERVATION TECHNIQUES ADVANCED SENSOR DEVELOPMENT LARGE DEPLOYABLE REFLECTOR STRUCTURAL EXPERIMENT	MODAL IDENTIFICATION EXPERIMENT S/C STRAIN AND ACOUSTIC SENSORS THERMAL INTERFACE TECHNOLOGY FLIGHT DYNAMICS IDENTIFICATION MICROBIOLOGICAL MONITOR FOR S/C ADV. STRUCTURAL DYN. AND CONTROL SOLAR ARRAY ENERGY STORAGE TECH. ADVANCED RADIATOR CONCEPTS THERMAL SHAPE CONTROL RISK-BASED FIRE SAFETY ACOUSTIC CONTROL TECHNOLOGY IN-SITU TRACE CONTAMINANTS ANALYSIS LIQUID STREAM TECHNOLOGY TEST BED ADVANCED AUTOMATION TECHNOLOGY ADVANCED ADAPTIVE CONTROL TWO PHASE FLUID BEHAVIOR AND MGT. POLYMER MATRIX COMPOSITES S/C MATERIALS AND COATINGS	LOW ACCELERATION AND PROPULSION TECHNOLOGY

EXPLORATION	OPERATIONS	ALL
FLIGHT CREW HEALTH REGENERATIVE LIFE SUPPORT SUBSYSTEM TESTING CRYO-TANK REPLACEMENT AND SERVICING EXPERIMENT	LASER COMMUNICATION TERMINAL FTS FORCE REACTION SYSTEM SPATIAL PERCEPTION AUDITORY REFLEX SEI VEHICLE SERVICING ROBOT FOR SCIENCE LABORATORIES ADVANCED OPTICAL RECEIVING STATION	HIGH STABILITY HYDROGEN MASER CLOCKS VHSIC FAULT TOLERANT PROCESSOR TRANSIENT UPSET PHENOMENA IN VLSIC INTERNAL IN-STEP EXTERNAL IN-STEP MICROELECTRONICS DATA SYSTEM EXP. GROWTH OF COMPOUND SEMICONDUCTOR CRYSTALS QUANTIZED VORTEX STRUCTURES IN SUPERFLUID He

INTEGRATED TRAFFIC MODEL

CARRIER	1991	1992	1993	1994	1995
SHUTTLE					
MIDDECK	MIDDECK 0-g DYNAMIC EXP.	ELECTROLYSIS EXP HEAT PIPE PERFORMANCE	MIDDECK ACTIVE CNTRL EXP LIQUID MOTION IN A ROTATING TANK		
GAS/CAP	TANK PRESS. CONTROL EXP.		THIN FOIL MIRROR MEAS. AND MOD. OF JOINT DAMP. PERM MEMBRANE TECH. EXP.	TWO-PHASE FLOW SPACE CRYOGENIC SYS. EXP.	
HITCHHIKER			THERMAL ENERGY STORAGE IN-FLIGHT CONTAMINATION EXP. EMULSION CHAMBER TECH. EXP. INVESTIG. OF S/C GLOW	THERMAL ENERGY STORAGE SOLAR ARRAY MOD. PLASMA INTERACTION EXPERIMENT JITTER SUPPRESSION	TANK VENTING SODIUM-SULFER BATTERY
CARGO BAY			LIDAR IN-SPACE TECH. EXP. FTS DTF-1		
SPACE HAB					
ELV					INFLATABLE PARABOLOID
NLS					
FREE FLYERS					
COMET					
EURECA				OPTICAL PROP. MONITOR	
SPARTAN				RETURN FLUX EXPERIMENT LASER OSCILLATOR SENSOR	
SPACE STATION					MODAL ID. EXP

INTEGRATED TRAFFIC MODEL

CONCLUDED

CARRIER	1996	1997	1998	1999	2000
SHUTTLE					
MIDDECK					
GAS/CAP					
HITCHHIKER					
CARGO BAY	AEROASSISTED FLIGHT EXP. ACCELERATION MEASUREMENT DEBRIS COLLISION WARNING SENSOR	RISK BASED FIRE SAFETY CRYOGENIC ORB. NITROGEN EX.			
SPACEHAB					
ELV	HYDROGEN MASER CLOCK SOLAR ELECTRIC PROP. EXP.	OPTICAL COMM. FLIGHT EXP.			
NLS					
FREE FLYERS					
COMET					
EURECA					
SPARTAN					
SPACE STATION	MANNED OBSERV. TECH. IN-SITU TRACE CONTAM. TRANSIENT UPSET PHENOMENA IN VLSIC VHSIC FAULT TOLERANT PROCESSOR ON-ORBIT DYN. MEAS. EXP MTC	S/C STRAIN & ACOUSTIC S. S/C MATERIALS & COAT. MICROELECTRONICS DATA SYSTEM LASER COMM TERMINAL* ACOUSTIC CONTROL TECH. INTERNAL IN-STEP ADVANCED SENSOR DEV. RESISTOJET EXP	EXTERNAL IN-STEP THERMAL INTERFACE TECH. FLIGHT DYNAMICS IDENT. POLYMER MATRIX COMPOSITES FLIGHT CREW HEALTH	LARGE DEPLOYABLE REFLECTOR STRUCT. EXP. LIQUID STREAM TECHNOLOGY CRYO-TANK REPLACEMENT AND SERVICING EXP. MICROBIOLOGICAL MONITOR FOR S/C REGENERATIVE LIFE SUPPORT DEBRIS MAPPING SENSOR PMC	ADVANCED ADAPTIVE CONTROL FTS FORCE REACT. SYS. SPATIAL PERCEPTION AUDITORY REFLEX EXP. ROBOT FOR SCI. LAB QUANTIZED VORTEX STRUCT IN He TWO PHASE FLUID BEHV. AND MANAGEMENT

*JOINT PROGRAM W/CODE S. CODE R DEVELOPING LASER COMPONENT
CODE S RESPONSIBLE FOR PAYLOAD DEVELOPMENT

TECHNOLOGY FLIGHT EXPERIMENTS

OAET

ADVISORY COMMITTEE MEMBERSHIP

CHAIRMAN
DR. M. FRANK ROSE, DIRECTOR, SPACE POWER INSTITUTE
AUBURN UNIVERSITY

EXECUTIVE SECRETARY
DR. JUDITH H. AMBRUS, ASSISTANT DIRECTOR
FOR SPACE TECHNOLOGY, NASA/OAET

MEMBERS

DR. STANLEY I. WEISS, VP & GENERAL MGR
R & D DIVISION, LMSC (RET)

DR. JOSEPH JANNI, CHIEF SCIENTIST
AF SPACE TECHNOLOGY CENTER

DR. EDWARD F. CRAWLEY, ASSOCIATE PROF.
OF AERONAUTICS AND ASTRONAUTICS, MIT

MR. JAMES B. ODOM, PRESIDENT, CEO
APPLIED RESEARCH INC.

DR. RAYMOND ASKEW, DIR. CCDS
AUBURN UNIV.

MR.HENRY HARTSFIELD, DEP. DIRECTOR,
SSF OPERATIONS, NASA/MSFC

DR. WILLIAM W. L. TAYLOR, CHIEF SCIENTIST,
SSF, NASA/OSF

DR. HERMAN A. REDIESS, MGR. AEROSPACE ENG.
SPARTA INC.

TECHNOLOGY FLIGHT EXPERIMENTS

OAET

ADVISORY COMMITTEE

- THE SPACE SYSTEMS AND TECHNOLOGY ADVISORY COMMITTEE (SSTAC) CHARTERED A SUBCOMMITTEE ON THE UTILIZATION FOR SPACE STATION FOR TECHNOLOGY DEVELOPMENT

  - TO REVIEW AND EVALUATE THE SSF FACILITIES FROM THE STANDPOINT OF THEIR USEFULNESS FOR RESEARCH AND ADVANCED TECHNOLOGY DEVELOPMENT AND VALIDATION

  - TO REVIEW AND EVALUATE OAET PLANNED EXPERIMENTS AND PROCEDURES FOR SELECTING ADDITIONAL PAYLOADS FOR SSF

  - TO EVALUATE THE PLANNED SSF UTILIZATION AND OPERATIONS PROCEDURES (MANIFESTING, INTEGRATION, CREW TRAINING, DATA TRANSMISSION, ETC) FROM THE VIEWPOINT OF TECHNOLOGY DEVELOPMENT NEEDS

TECHNOLOGY FLIGHT EXPERIMENTS

OAET

SPECIAL ISSUES

- THE TECHNOLOGY FLIGHT EXPERIMENTS EMPHASIS ARE LIKELY TO BE ON SMALL, INEXPENSIVE EXPERIMENTS

    - MIDDECK LOCKER OR GAS CAN ON SHUTTLE HAS PROVEN TO BE VERY COST EFFECTIVE

- THE TECHNOLOGY DEVELOPMENT COMMUNITY IS HAS MAJOR INTEREST IN REDUCING COST AND INCREASING FREQUENCY OF EXPERIMENTATION

    - STANDARD DRAWERS WITH SIMPLE INTERFACES
    - SIMPLE, INEXPENSIVE ANALYTICAL INTEGRATION
    - SIMPLE COMMUNICATIONS LINK BETWEEN PI AND EXPERIMENT

TECHNOLOGY FLIGHT EXPERIMENTS

OAET

SUMMARY

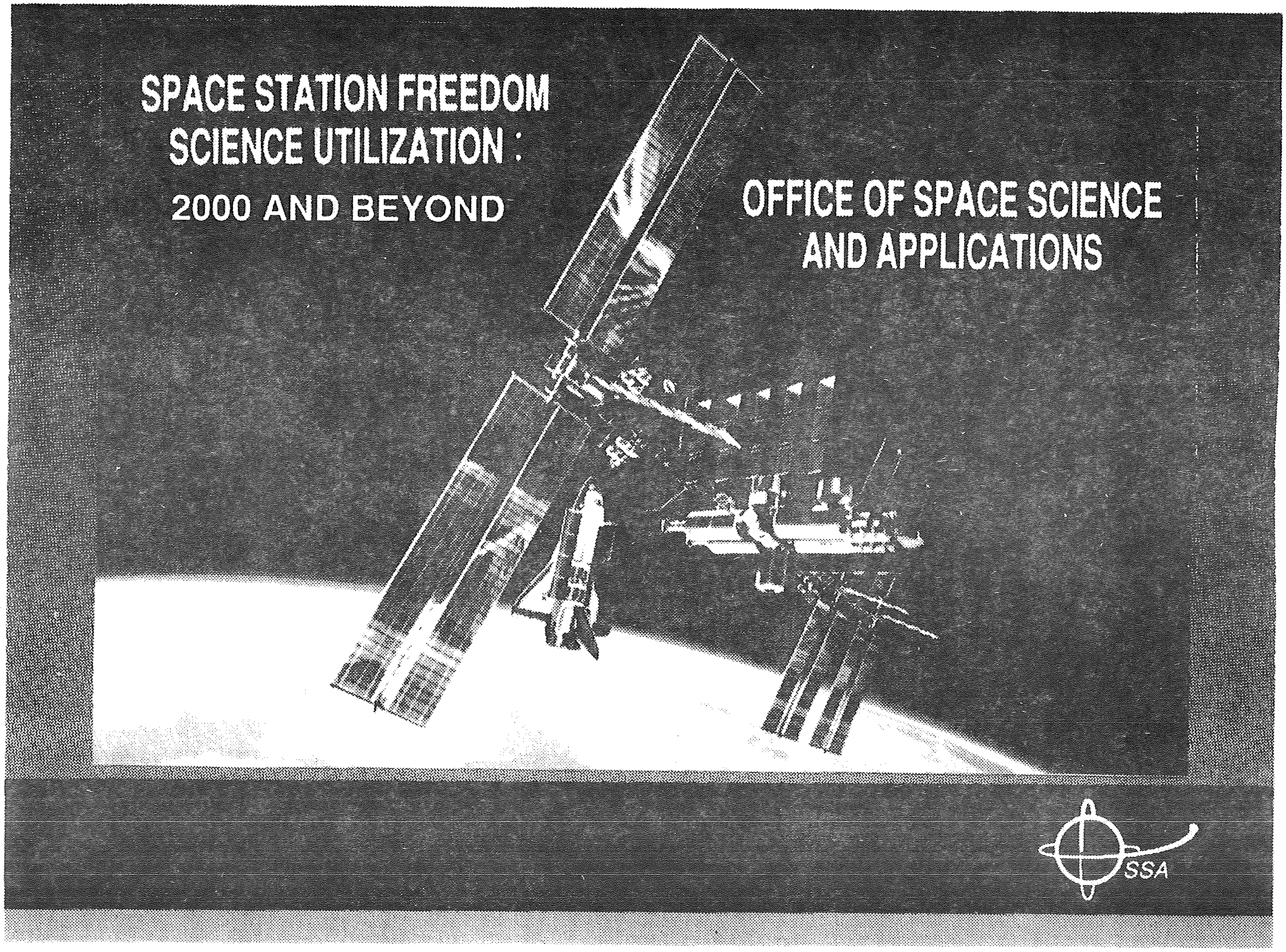
- TECHNOLOGY FLIGHT EXPERIMENTS ARE AN IMPORTANT AND INTEGRAL PART OF TECHNOLOGY DEVELOPMENT AND VERIFICATION

- SPACE STATION FREEDOM IS RECOGNIZED AS A KEY FACILITY TO UTILIZE FOR THIS PURPOSE

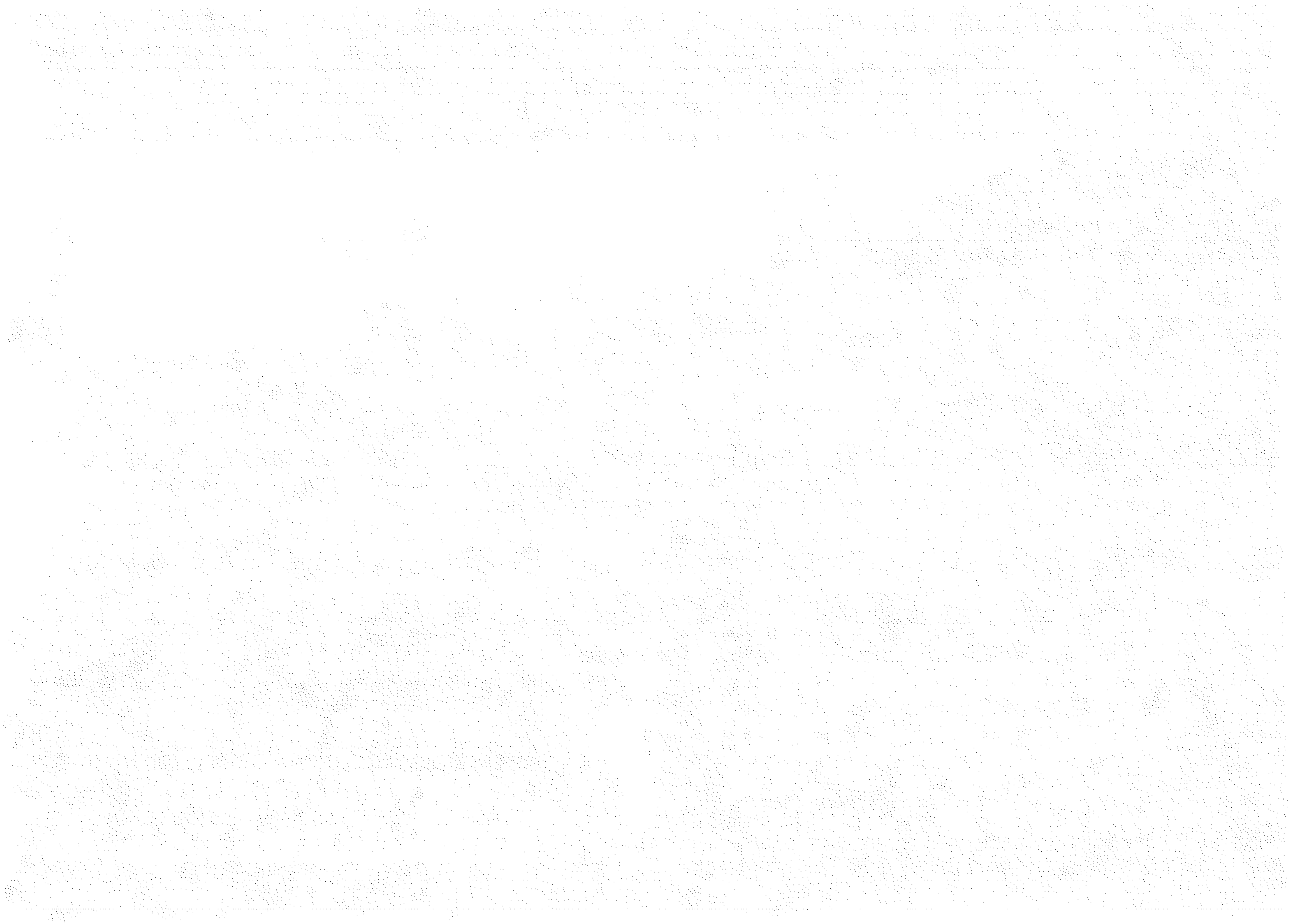
- THE STRESS WILL BE ON SMALL EXPERIMENTS, SIMPLE INTERFACES AND SIMPLE INTEGRATION PROCEDURES

- TECHNOLOGY DEVELOPMENT AND VERIFICATION IS EXPECTED TO USE AT LEAST 15-20% OF SSF RESOURCES AND WILL INCLUDE

  - OAET EXPERIMENTS
  - INDUSTRY (IR&D DEVELOPED) EXPERIMENTS
  - UNIVERSITY EXPERIMENTS
  - DOD EXPERIMENTS


SPACE STATION FREEDOM
SCIENCE UTILIZATION :
2000 AND BEYOND
OFFICE OF SPACE SCIENCE
AND APPLICATIONS
OSSA

91 1 4494 01

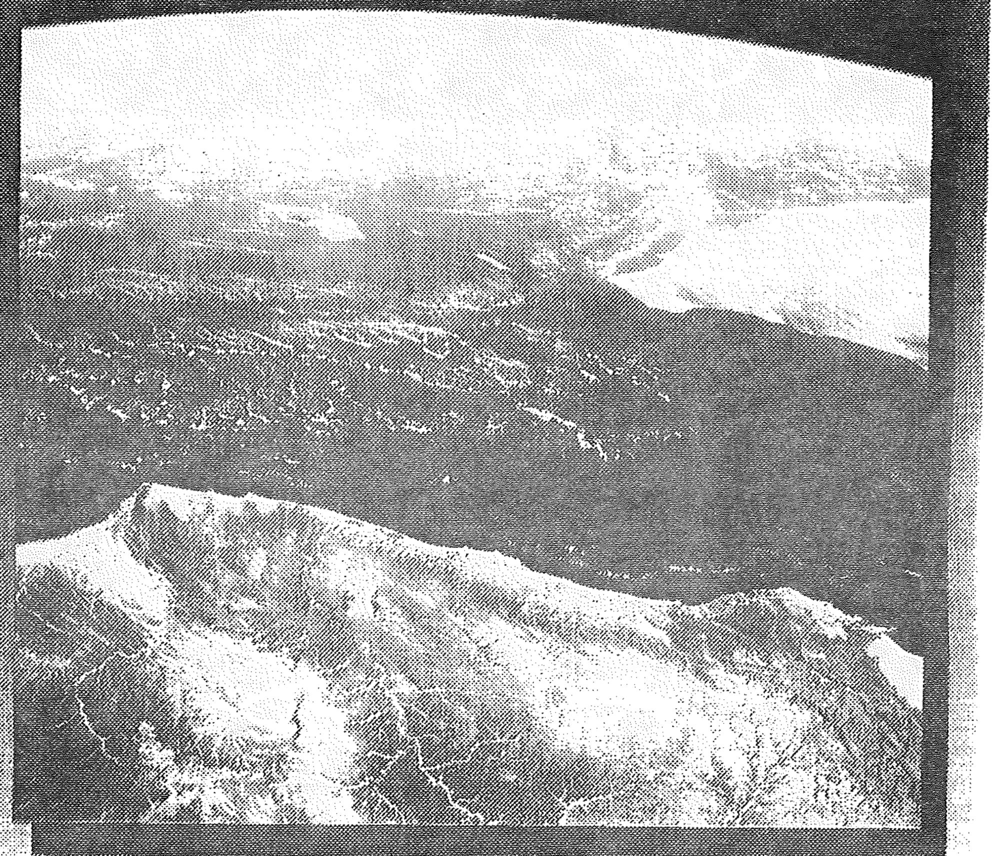


OFFICE OF SPACE SCIENCE AND APPLICATIONS GOALS

TO ADVANCE SCIENTIFIC KNOWLEDGE OF THE PLANET EARTH, THE SOLAR SYSTEM, AND THE UNIVERSE.

TO UNDERSTAND THE EFFECTS OF THE SPACE ENVIRONMENT ON BIOLOGICAL AND PHYSICAL PROCESSES.

TO EXPAND THE HUMAN PRESENCE BEYOND THE EARTH INTO THE SOLAR SYSTEM.

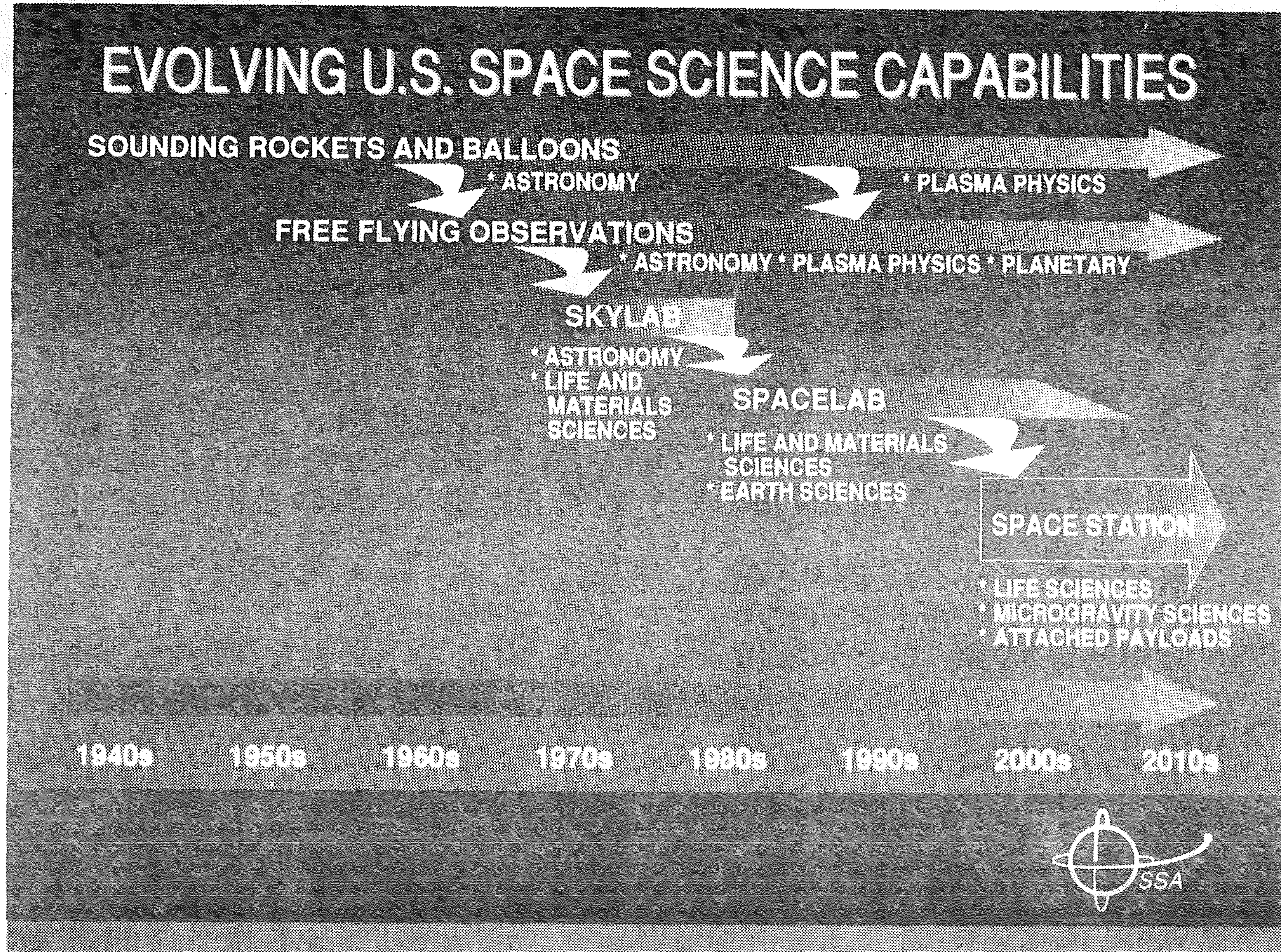


90 184202 MAR

STRATEGIC PLAN

- COMPLETE THE ONGOING PROGRAM
- INITIATE A MAJOR OR MODERATE MISSION EACH YEAR
- INITIATE SMALL MISSIONS FOR INCREASED OPPORTUNITIES
- TRANSITION TO SPACE STATION FREEDOM
- MAINTAIN AND AUGMENT THE RESEARCH BASE

ORIGINAL PAGE IS OF POOR QUALITY



91 1 4494 02

ORIGINAL PAGE IS OF POOR QUALITY

OSSA STRATEGY FOR BASELINE SPACE STATION SCIENCE UTILIZATION

TREAT STATION UTILIZATION AS AN INTEGRAL ELEMENT OF THE OVERALL SPACE SCIENCES PROGRAM

AVOID DUPLICATION AND MAXIMIZE USER OPPORTUNITIES BY COORDINATING PLANS AMONG SCIENCE GROUPS (U.S. AGENCIES, INTERNATIONAL PARTNERS)

ENSURE THAT STATION IS THE APPROPRIATE PLATFORM FOR THE SCIENCE IN QUESTION

PROMOTE DISCIPLINE-DRIVEN UTILIZATION

→ EVOLUTIONARY APPROACH TO UTILIZATION: RELY ON MODEST EXPERIMENTATION INITIALLY, INTRODUCE MORE AMBITIOUS EXPERIMENTATION AS WE "LEARN HOW TO USE THE STATION"

NASA

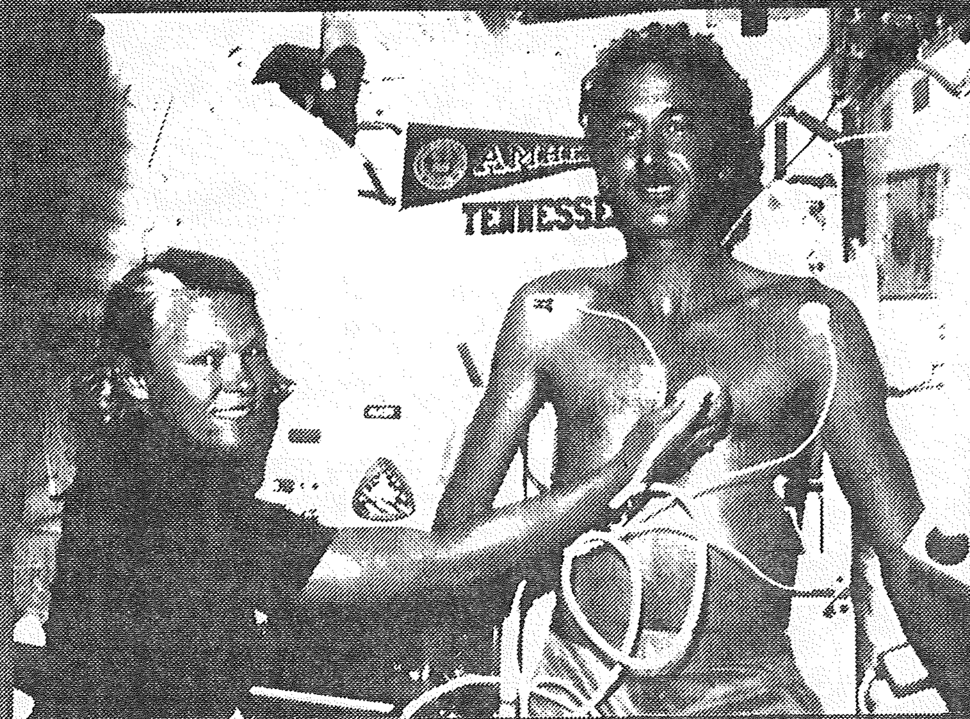
OSSA

LIFE SCIENCES GOALS

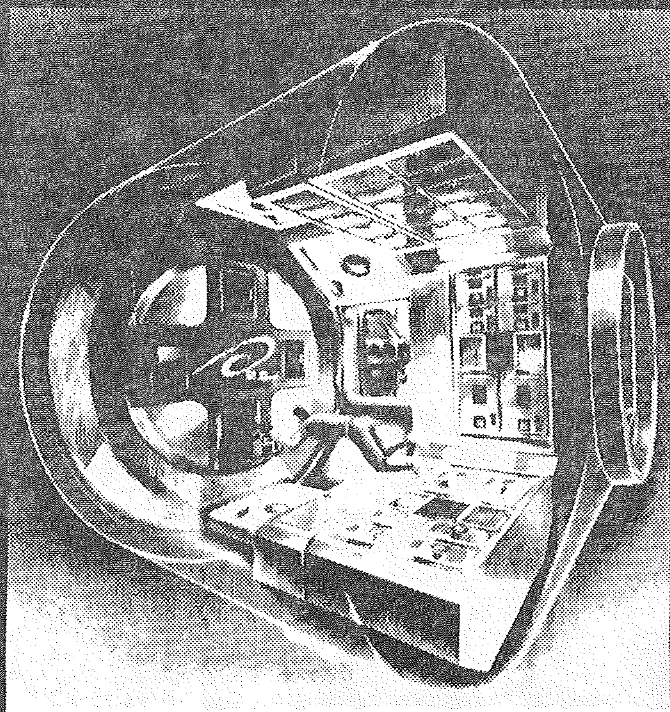
TO DEVELOP MEDICAL AND BIOLOGICAL SYSTEMS THAT ENABLE THE HUMAN EXPLORATION AND HABITATION OF SPACE.

TO UNDERSTAND THE ORIGIN, EVOLUTION, AND DISTRIBUTION OF LIFE IN THE UNIVERSE.

TO UNDERSTAND THE RELATIONSHIP BETWEEN LIFE AND GRAVITY AND OTHER PLANETARY PROPERTIES.



LIFE SCIENCES FACILITIES



CENTRIFUGE FACILITY

- CENTRIFUGE
- GRAVITATIONAL BIOLOGY
- SPACE PHYSIOLOGY
- GAS-GRAIN SIMULATION
- CLOSED ECOLOGICAL LIFE SUPPORT SYSTEM TEST FACILITY

SSA

91 1 4494 08

ORIGINAL PAGE IS OF POOR QUALITY

OSSA SPACE STATION PAYLOAD TRAFFIC MODEL MAY 1991

Life Sciences Pressurized Volume Payloads

Calendar Year	1996	1997	1998	1999	2000	2001	2002	2003
CENTRIFUGE FACILITY Centrifuge (CF) Habitat Holding Facility				2.5 m CF		UNDER REVIEW		
Gravitational Biology Facility								
EVA/Space Physiology Facility/BMAC	EVA			SP/BMAC				
Gas-Grain Simulation Facility								
CELSS Test Facility								
Rack Outfitting	2		4	6[2] + CF				
Cum. Racks On Station	2	2	6	10 + CF	10 + CF			

KEY

[ ] RACKS REMOVED

1 Space Station Double Rack

1 Space Station Double Rack - Removed

NASA

OSSA

LIFE SCIENCES: PRE-PMC

PHASE I: EVA/HUMAN PHYSIOLOGY

- COMMENCES WITH MTC

- RESEARCH FOCUSING ON THE PHYSIOLOGICAL RESPONSES TO REPEATED EVA, AND MONITORING OF HUMAN HEALTH AND ENVIRONMENT OF SSF. SPECIFIC AREAS OF RESEARCH WILL INCLUDE:
  - PULMONARY STUDIES
  - CARDIOVASCULAR RESEARCH
  - METABOLIC AND MUSCULOSKELETAL STUDIES
  - NEUROSCIENCE RESEARCH

NASA

SSA

LIFE SCIENCES: PRE-PMC

PHASE II: LIFE SCIENCES/LIFE SUPPORT

- COMMENCE AROUND PMC

- BIOMEDICAL AND LIFE SUPPORT RESEARCH ACTIVITIES WILL BE INITIATED DURING THIS PHASE TO:

  - EXPAND UNDERSTANDING OF BASIC HUMAN PHYSIOLOGY IN WEIGHTLESSNESS

  - DEVELOP BIOREGENERATIVE LIFE SUPPORT SYSTEM TO SUPPORT CREW HEALTH MAINTENANCE

NASA

SSA

C-3

LIFE SCIENCES: POST-PMC

PHASE III: MEETING EXPANDED SCIENCE AND OPERATIONAL REQUIREMENTS

CURRENT PLANNING CALLS FOR AN INTERNATIONAL LIFE SCIENCES RESEARCH FACILITY ON SSF TO SUPPORT CONTINUOUS SCIENTIFIC INVESTIGATIONS FOR MORE THAN 20 YEARS FOR:

- RESEARCH DEVOTED TO INDEPTH STUDY IN MEDICAL AND BIOLOGICAL DISCIPLINES OVER PROLONGED PERIODS OF TIME
- ESTABLISHING A CAPABILITY TO ADDRESS MEDICAL ISSUES WHICH WILL ENABLE LONG DURATION HUMAN EXPLORATION MISSIONS

LIFE SCIENCES: POST-PMC

BY THE YEAR 2001, THE FOLLOWING CAPABILITIES WILL BE AVAILABLE TO BE USED FOR THE NEXT TWO DECADES ABOARD SSF:

- **THE GRAVITATIONAL BIOLOGY FACILITY (CENTRIFUGE):** CONTROLLED LEVELS OF ARTIFICIAL GRAVITY TO SEPARATE THE EFFECTS OF WEIGHTLESSNESS FROM OTHER ENVIRONMENTAL FACTORS

- **THE CELSS TEST FACILITY:** CONTROL, MONITOR, AND EVALUATE THE GROWTH OF CROP PLANTS AS A MEANS OF STUDYING BIOREGENERATIVE SUBSYSTEMS

- **GAS-GRAIN SIMULATION FACILITY:** STUDY CHEMICAL AND PHYSICAL PROCESSES SUCH AS THE FORMATION, GROWTH, ACCRETION, AND INTERACTION OF CLOUDS, DUST GRAINS, AND OTHER PARTICLES IN MICROGRAVITY

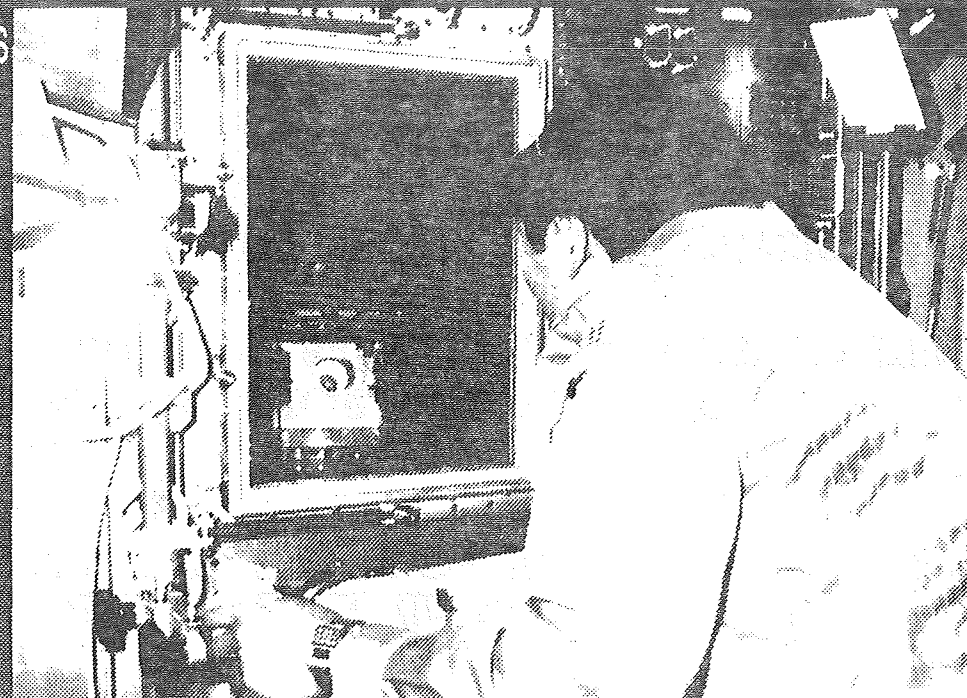
MICROGRAVITY SCIENCE AND APPLICATIONS GOALS

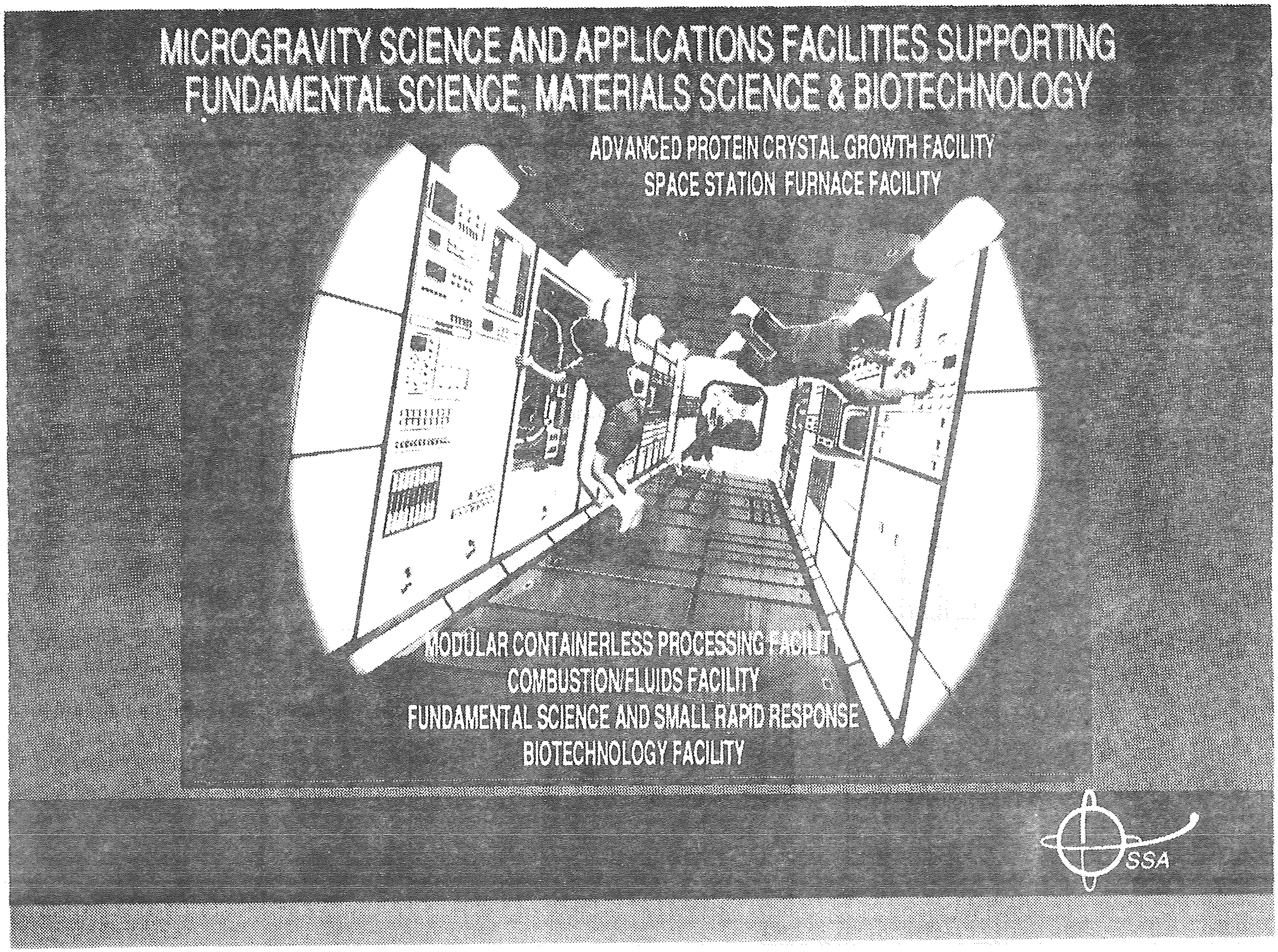
TO INVESTIGATE THE BEHAVIOR OF MATERIALS AND FLUIDS AND THE EFFECTS ON PROCESSES CARRIED OUT IN THE MICROGRAVITY ENVIRONMENT,

TO PROVIDE A BETTER UNDERSTANDING OF THE EFFECTS AND LIMITATIONS IMPOSED BY GRAVITY ON PROCESSES CARRIED OUT ON EARTH,

TO EVOLVE PROCESSES THAT EXPLOIT THE UNIQUE CHARACTERISTICS OF THE MICROGRAVITY ENVIRONMENT OF SPACE TO ACCOMPLISH RESULTS THAT CANNOT BE OBTAINED ON EARTH, AND

TO EXPLORE AND DETERMINE POTENTIAL APPLICATIONS FOR COMMERCIALIZATION IN SPACE.



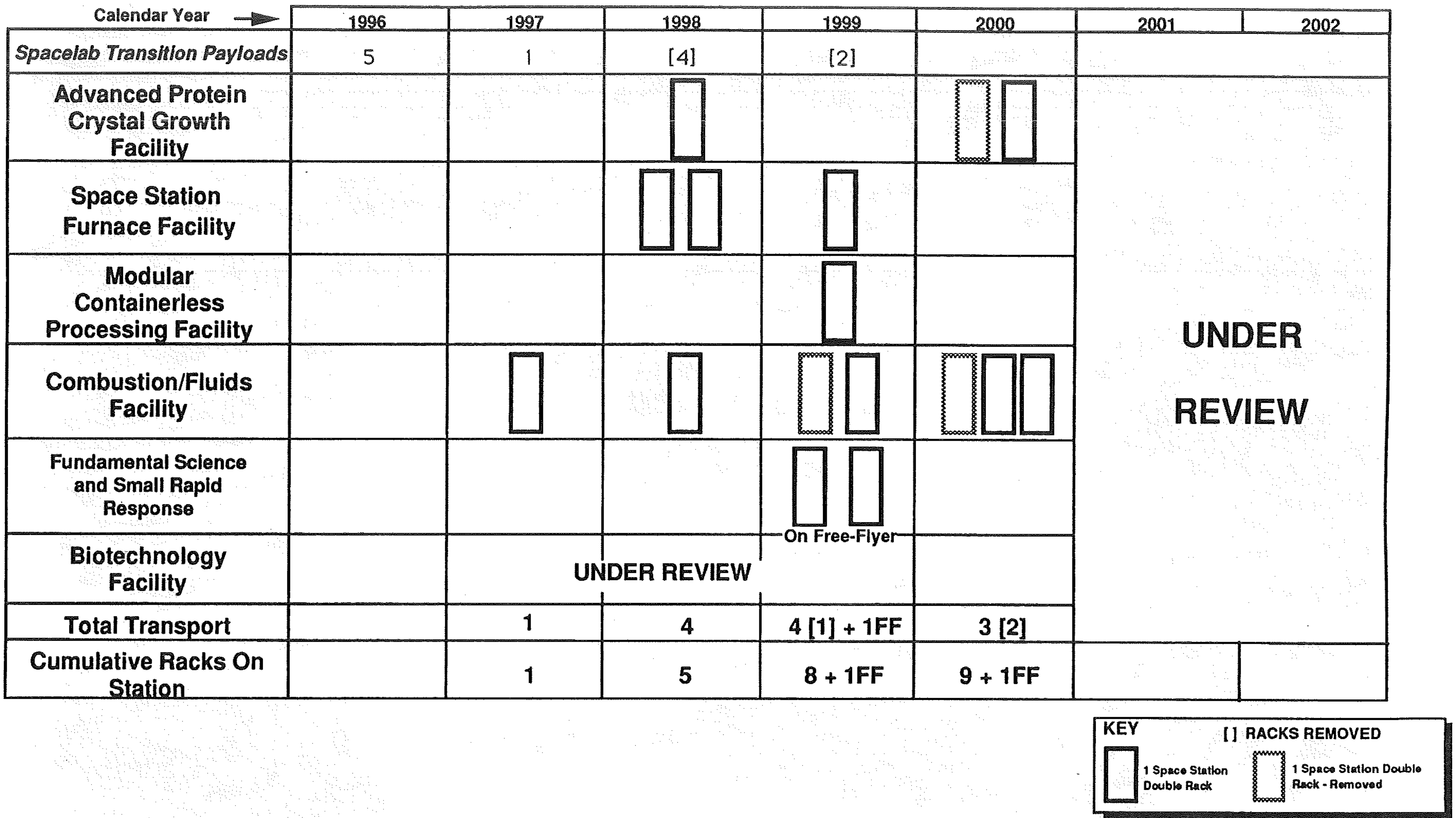


91 1-4494 09

ORIGINAL PAGE IS OF POOR QUALITY

OSSA SPACE STATION PAYLOAD TRAFFIC MODEL MAY 1991

Microgravity Science and Applications Pressurized Volume Payloads



MICROGRAVITY SCIENCE & APPLICATIONS: PRE-PMC

PHASE I: MAN-TENDED/TRANSITION HARDWARE

- COMMENCES WITH MTC TO MID-1998
- EMPHASIS ON USING HARDWARE ORIGINALLY DESIGNED FOR SHUTTLE BUT ADAPTED TO SSF
- EXPERIMENTS IN MATERIALS SCIENCE, FLUID PHYSICS AND DYNAMICS RESEARCH, AND PROTEIN CRYSTAL GROWTH EXPERIMENTS

NASA

SSA

MICROGRAVITY SCIENCE & APPLICATIONS: PRE-PMC

PHASE II: MAN-TENDED/FACILITY-CLASS HARDWARE

- 1998-99 TO PMC
- RESEARCH TO CONTINUE IN MATERIALS SCIENCE, FLUIDS, AND PROTEIN CRYSTAL GROWTH DISCIPLINES, BUT WILL ADDRESS MORE MATURE SETS OF QUESTIONS
- COMBUSTION SCIENCE TO BE STUDIED (PREREQUISITE FOR OUTER PLANET EXPLORATION)

NASA

OSSA

MICROGRAVITY SCIENCE & APPLICATIONS: POST-PMC

PHASE III: PERMANENT MANNED PRESENCE

- PMC ONWARD
- ALLOWS ITERATIVE SETS OF ON-ORBIT EXPERIMENTS REQUIRING EXTENDED PERIODS OF MANNED INTERACTION AND INTERPRETATION

NASA

SSA

MICROGRAVITY SCIENCE & APPLICATIONS: POST-PMC

PHASE IV: MAN-TENDED FREE FLYER

- BASED ON RESULTS FROM PREVIOUS PHASES, CERTAIN CLASSES OF EXPERIMENTS REQUIRING LONG EXPERIMENTS TIMES AND LOWER-GRAVITY LEVELS WILL MIGRATE TO FREE FLYER
- EXPERIMENTS WILL INCLUDE GROWTH OF TECHNOLOGICALLY IMPORTANT ELECTRONIC AND OPTO-ELECTRONIC MATERIALS

NASA

SSA

MICROGRAVITY SCIENCE & APPLICATIONS: POST-PMC

BY THE YEAR 2001, THE FOLLOWING CAPABILITIES WILL BE AVAILABLE TO BE USED FOR THE NEXT TWO DECADES ABOARD SSF:

ADVANCED PROTEIN CRYSTAL GROWTH FACILITY: Evaluate the effects of gravity on the growth of protein crystals and study the physics/dynamics of crystal growth

SPACE STATION FURNACE FACILITY: Explore potential for using low gravity environment to develop unique materials or materials structures

MODULAR COMBUSTION FACILITY: Provide better understanding of fundamental theories of combustion processes; provide data for combustion-related applications such as spacecraft fire safety

MICROGRAVITY SCIENCE & APPLICATIONS: POST-PMC

<u>FLUID PHYSICS DYNAMICS FACILITY:</u> Provide better understanding of fundamental theories of fluids processes; provide data for fluids-related applications

<u>MODULAR CONTAINERLESS PROCESSING FACILITY:</u> Conduct research on properties and phenomena that on Earth are seriously affected by container contamination

<u>BIOTECHNOLOGY FACILITY:</u> Culture tissue models for genetic regulations studies, and study function and differentiation in low mechanical stress environment

NASA

OSSA

FINAL OBSERVATIONS

- OSSA WILL TAKE AN EVOLUTIONARY APPROACH TO SCIENCE ONBOARD STATION
- MANY PRIOR AREAS OF CONCERN WITH STATION CAPABILITIES (I.E., POWER) HAVE IMPROVED; MORE ARE ON THE PATH TO RESOLUTION
- SCIENCE REQUIREMENTS AND PROGRAMS WILL TEND TO ADJUST TO REALISTIC STATION CAPABILITIES
- THERE ARE NO MAJOR OSSA INFRASTRUCTURE REQUIREMENTS FOR POST-PMC PERIOD

NASA

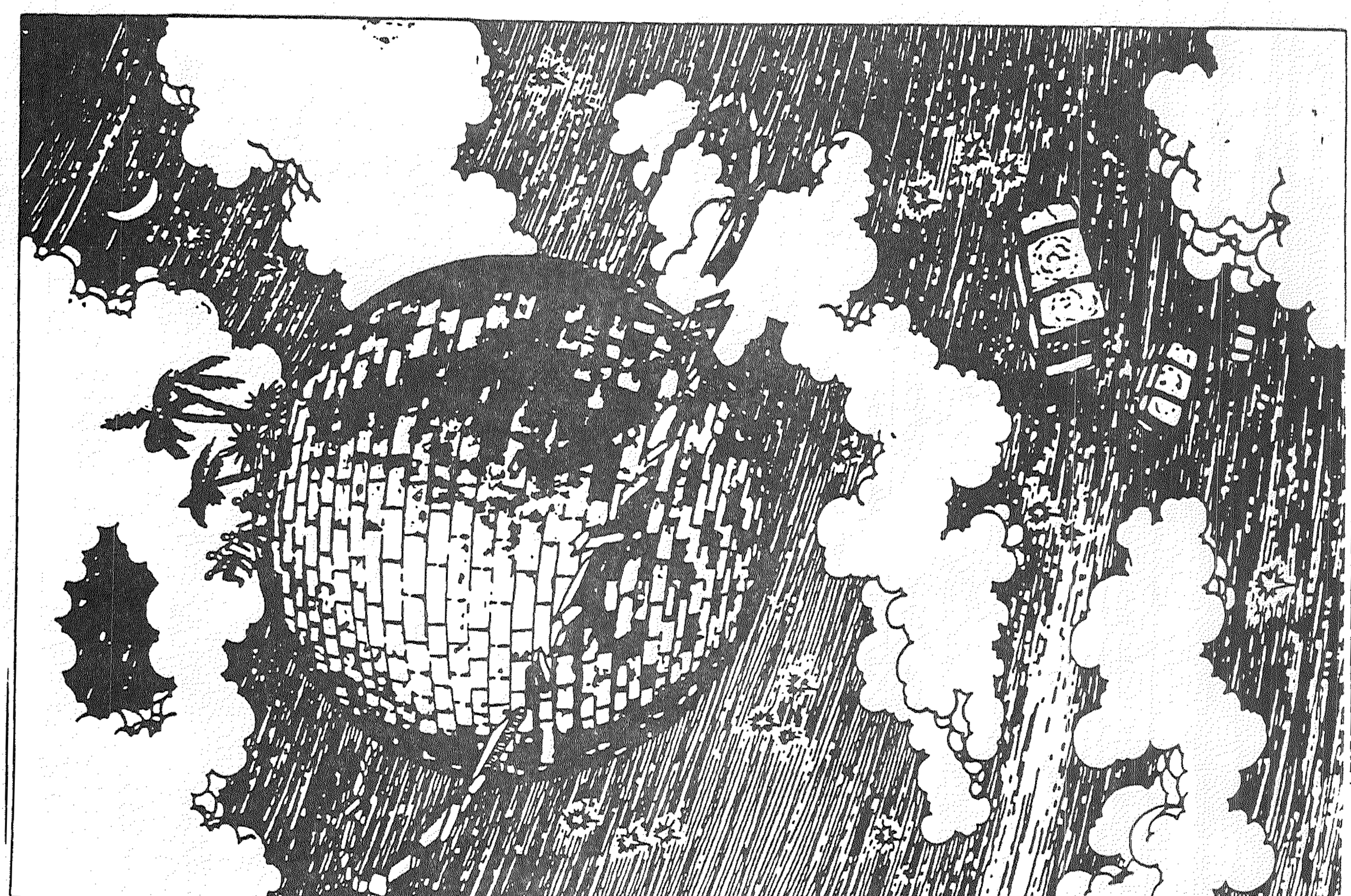
OSSA

Space Directorate

A HISTORICAL PERSPECTIVE ON SPACE STATION

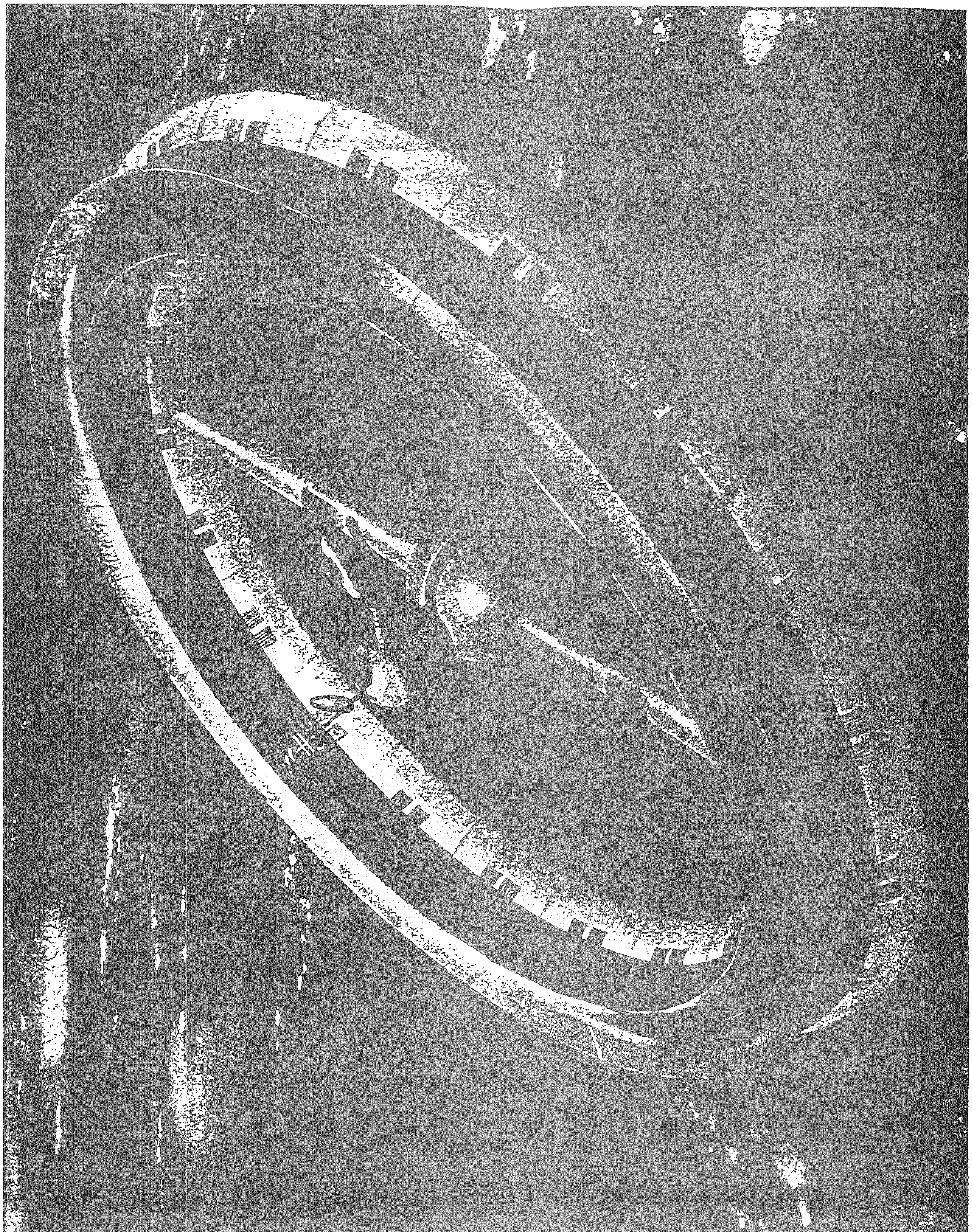
W. RAY HOOK
DIRECTOR FOR SPACE
LANGLEY RESEARCH CENTER

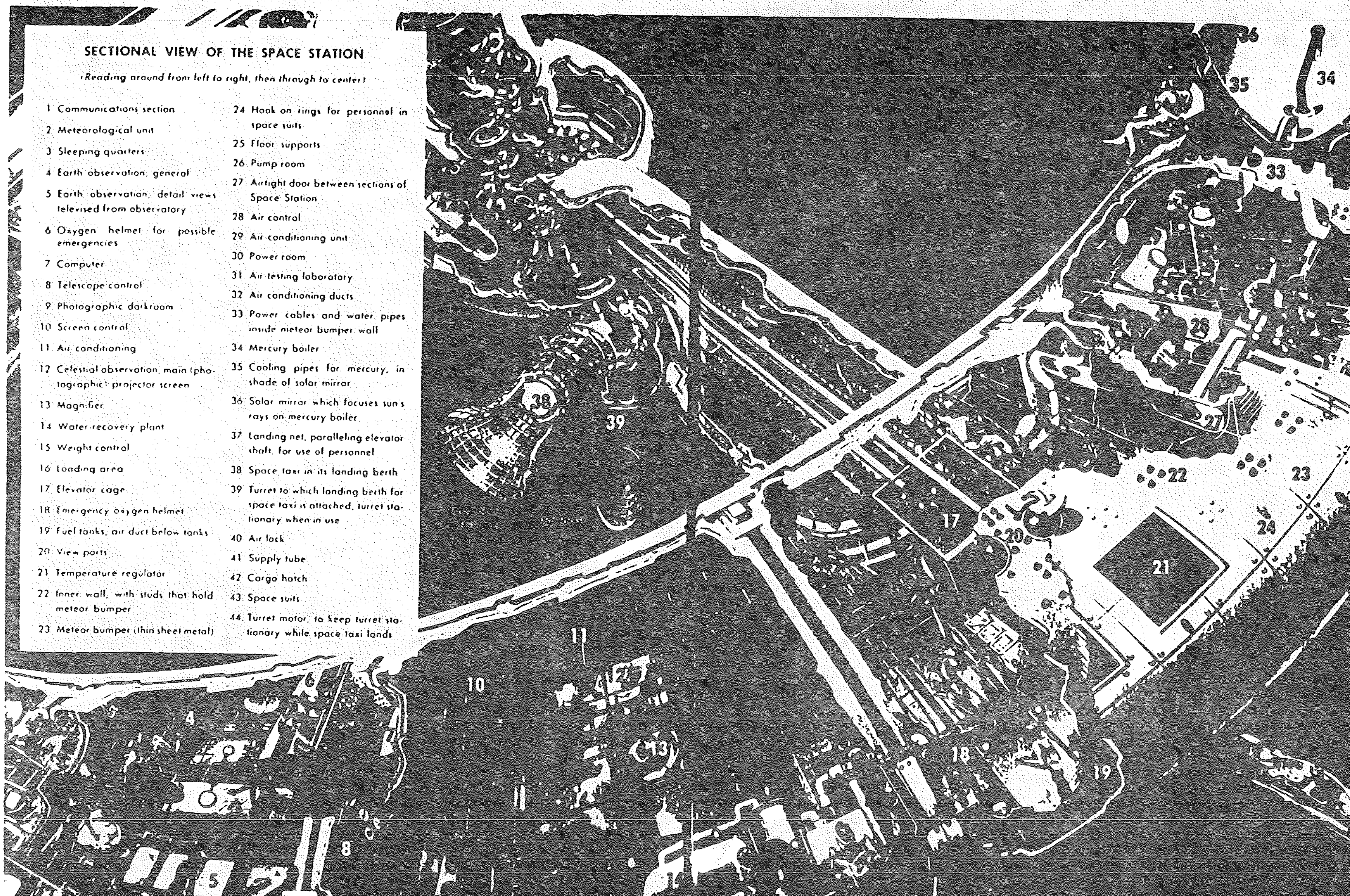
SPACE STATION EVOLUTION
BEYOND THE BASELINE
SOUTH SHORE HARBOUR RESORT AND CONFERENCE CENTER
LEAGUE CITY, TEXAS
AUGUST 7, 1991



PRECEDING PAGE BLANK NOT FILMED

PAGE 204 INTENTIONALLY BLANK

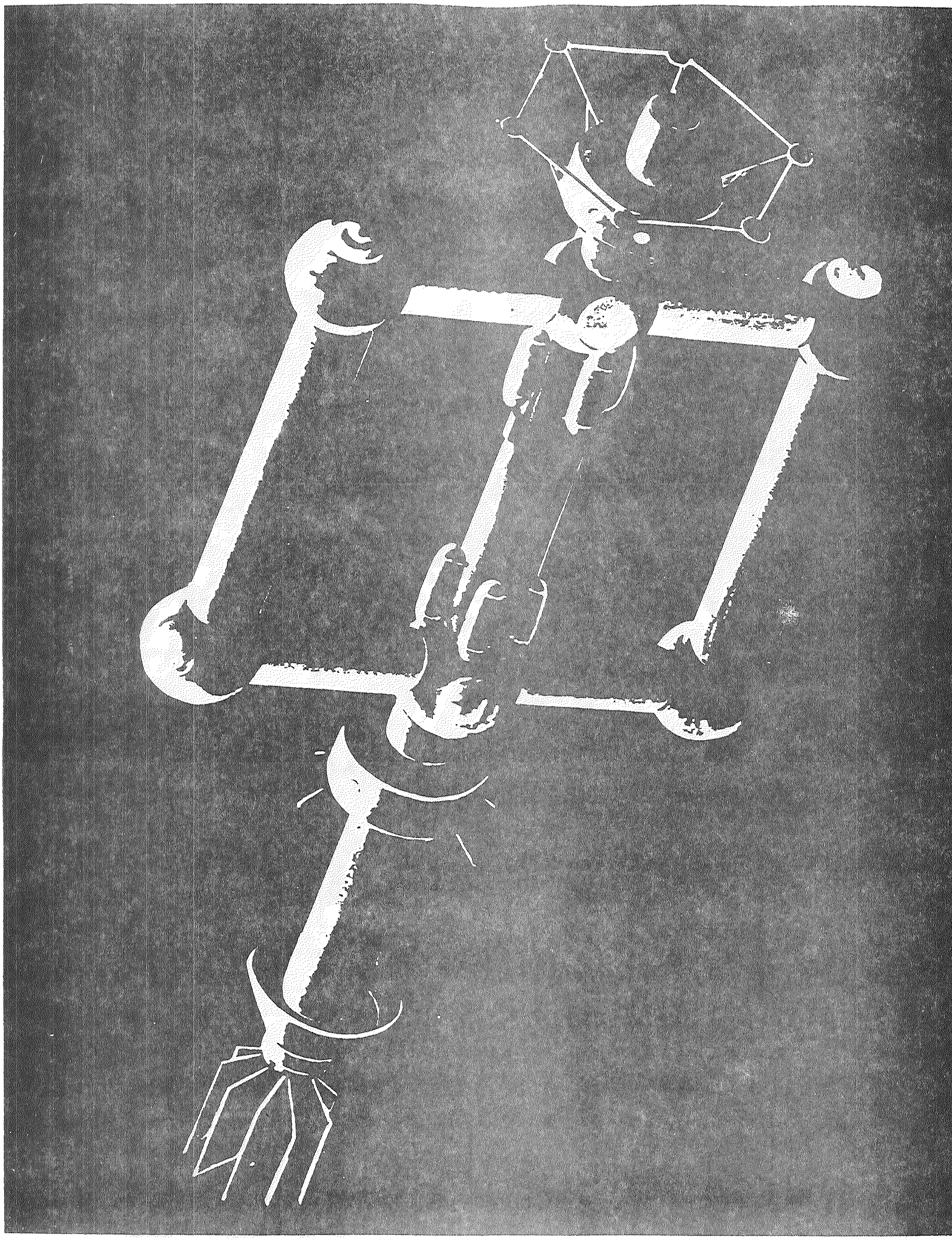


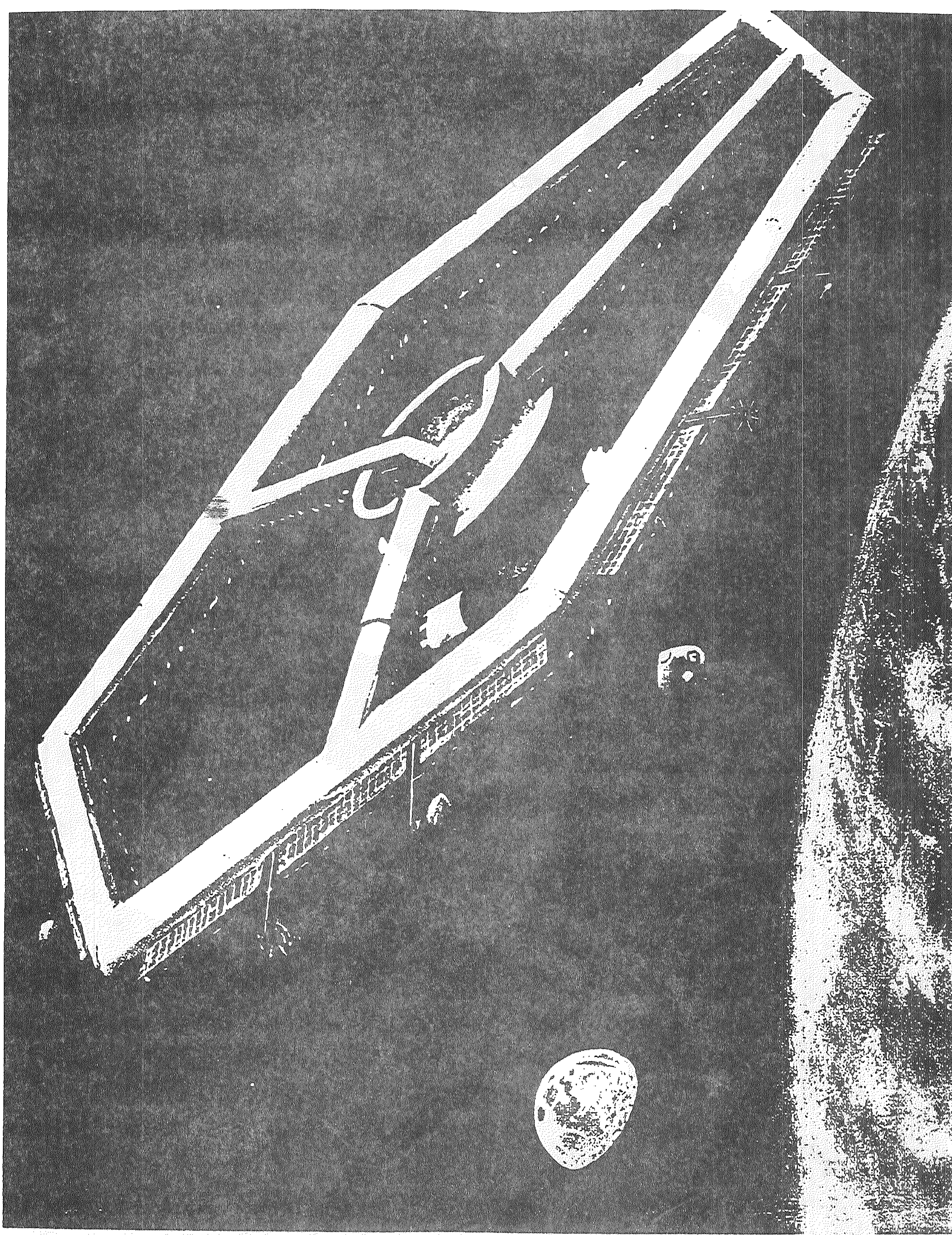


SECTIONAL VIEW OF THE SPACE STATION

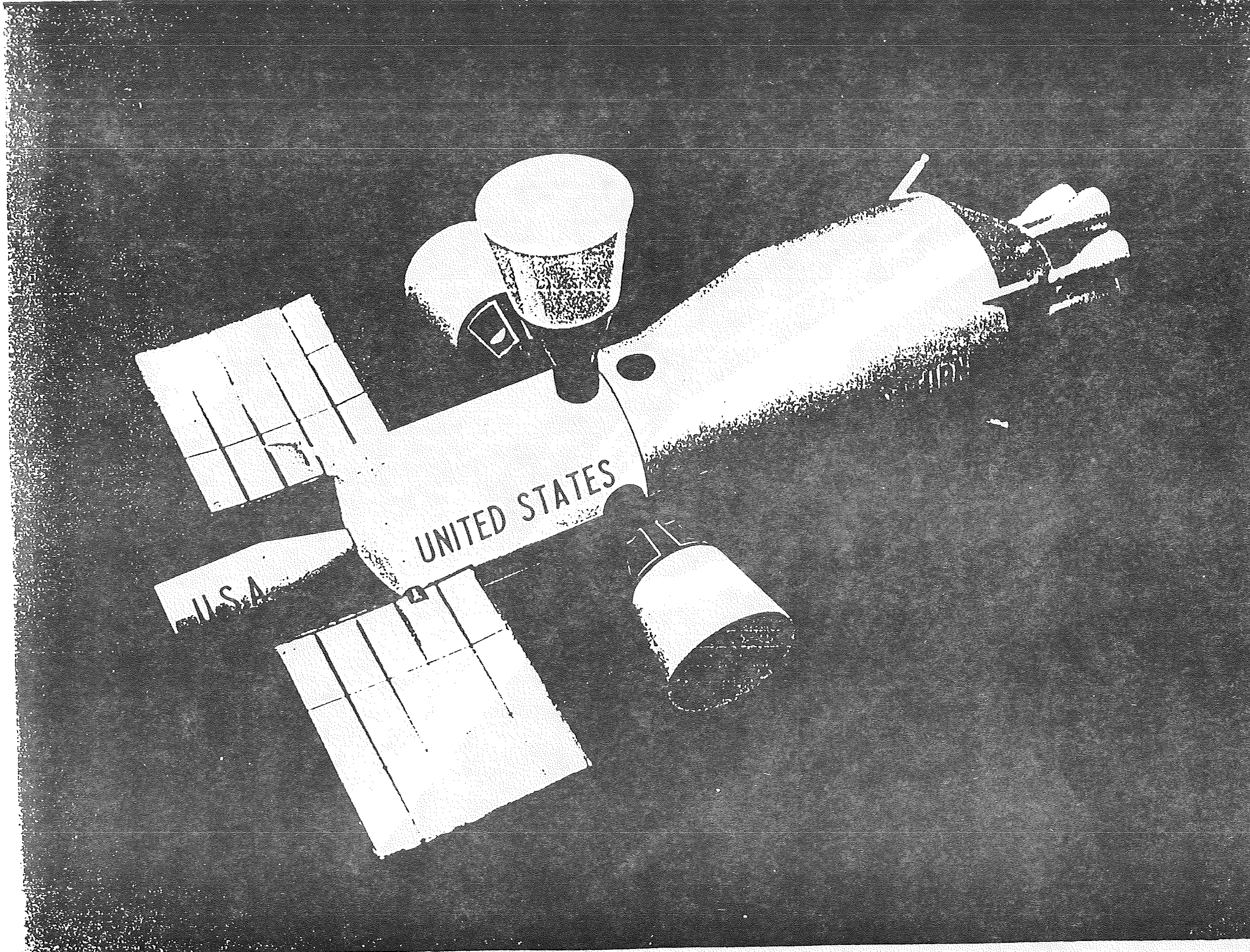
(Reading around from left to right, then through to center)

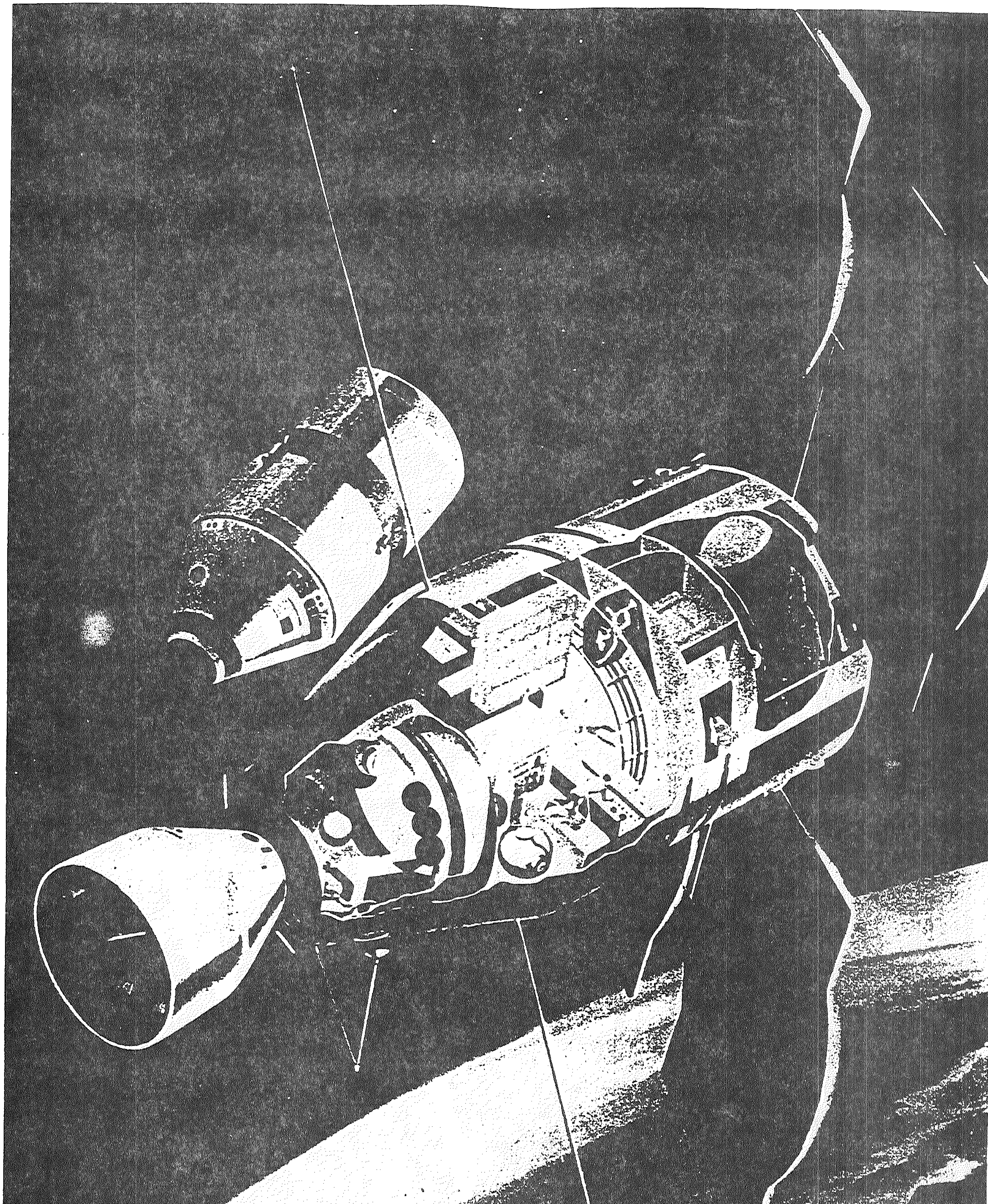
1 Communications section
2 Meteorological unit
3 Sleeping quarters
4 Earth observation, general
5 Earth observation, detail views televised from observatory
6 Oxygen helmet for possible emergencies
7 Computer
8 Telescope control
9 Photographic darkroom
10 Screen control
11 Air conditioning
12 Celestial observation, main (photographic) projector screen
13 Magnifier
14 Water-recovery plant
15 Weight control
16 Loading area
17 Elevator cage
18 Emergency oxygen helmet
19 Fuel tanks, air duct below tanks
20 View ports
21 Temperature regulator
22 Inner wall, with studs that hold meteor bumper
23 Meteor bumper (thin sheet metal)
24 Hook on rings for personnel in space suits
25 Floor supports
26 Pump room
27 Airtight door between sections of Space Station
28 Air control
29 Air-conditioning unit
30 Power room
31 Air-testing laboratory
32 Air conditioning ducts
33 Power cables and water pipes inside meteor bumper wall
34 Mercury boiler
35 Cooling pipes for mercury, in shade of solar mirror
36 Solar mirror which focuses sun's rays on mercury boiler
37 Landing net, paralleling elevator shaft, for use of personnel
38 Space taxi in its landing berth
39 Turret to which landing berth for space taxi is attached, turret stationary when in use
40 Air lock
41 Supply tube
42 Cargo hatch
43 Space suits
44 Turret motor, to keep turret stationary while space taxi lands

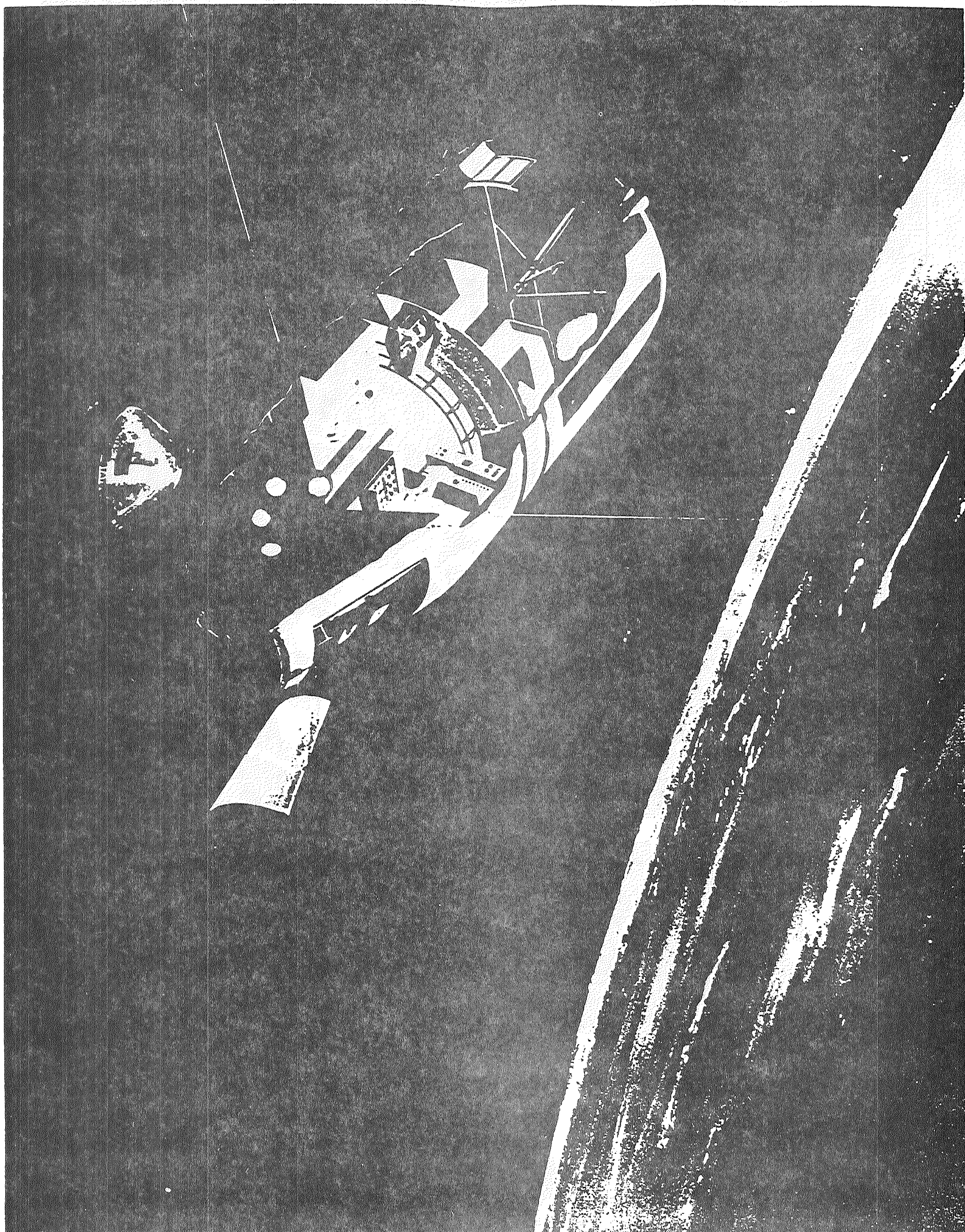


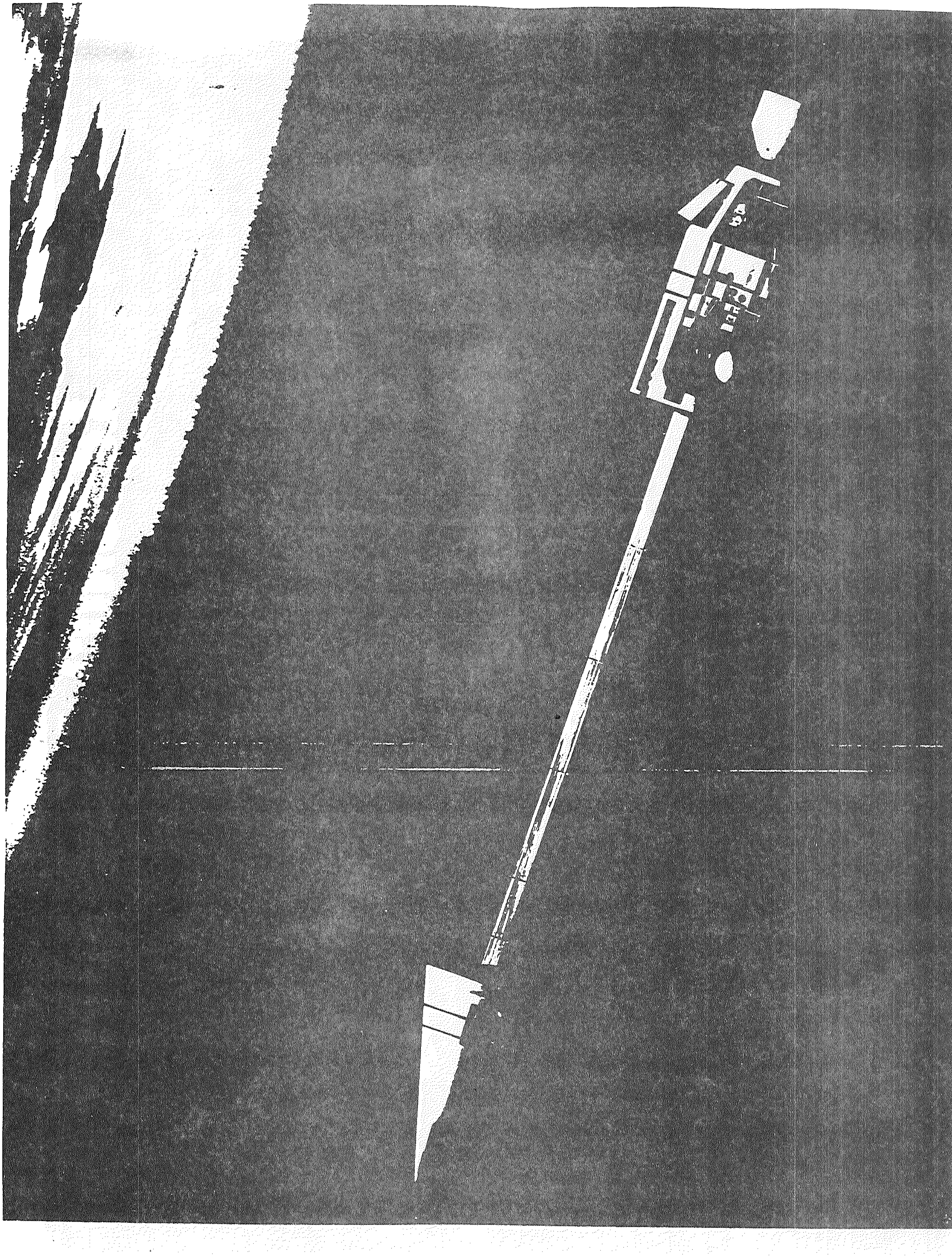


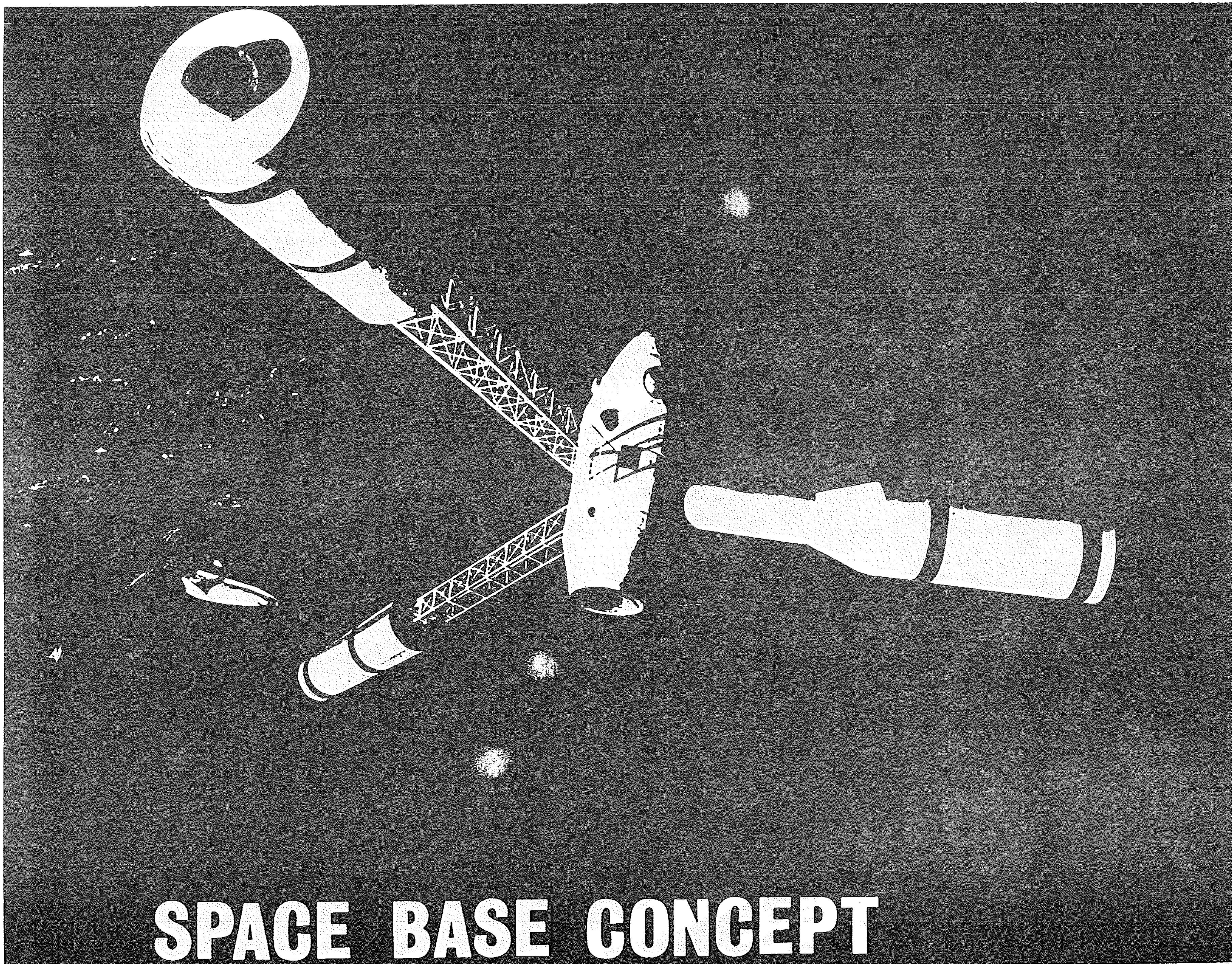
NASA
L-63-3750



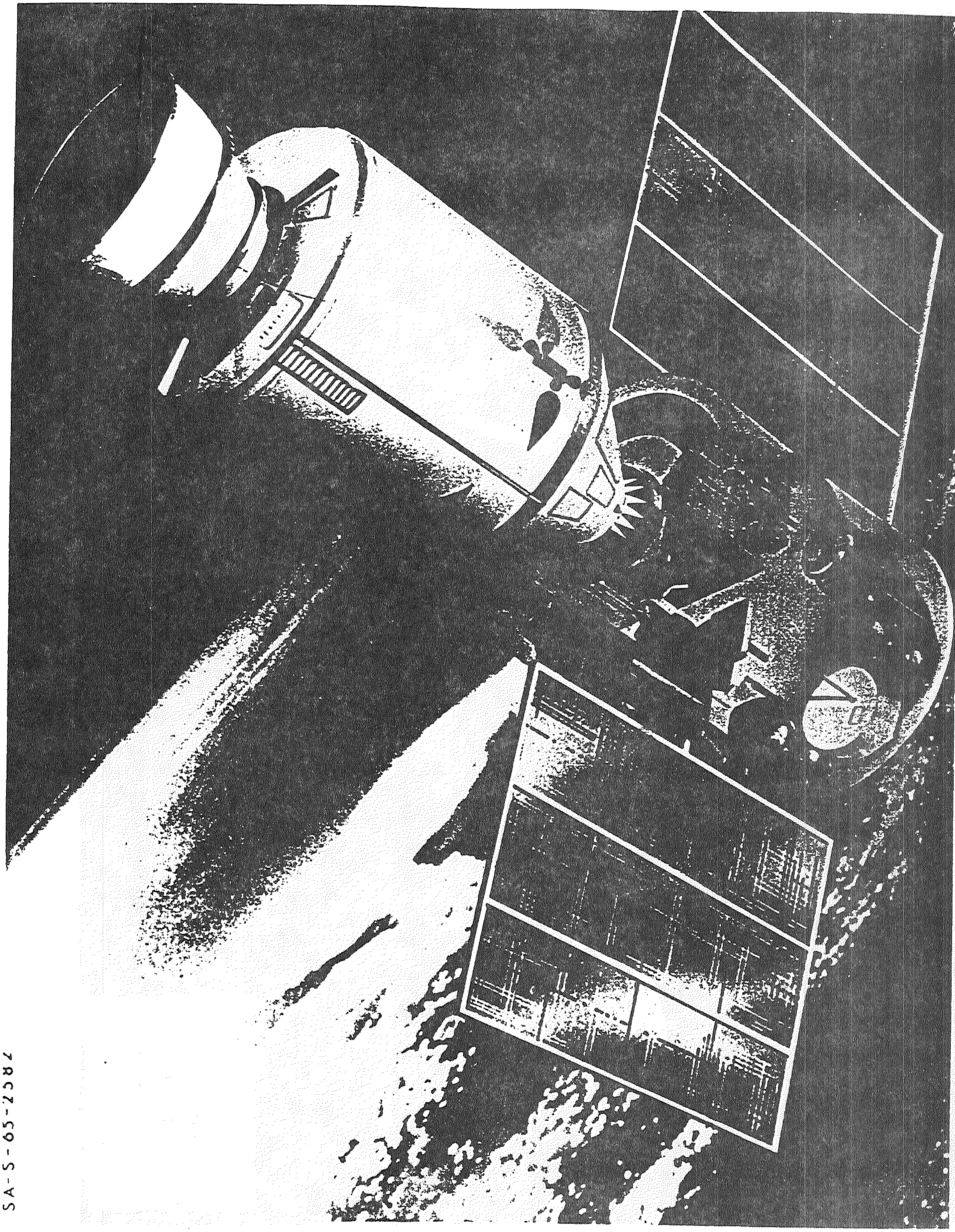


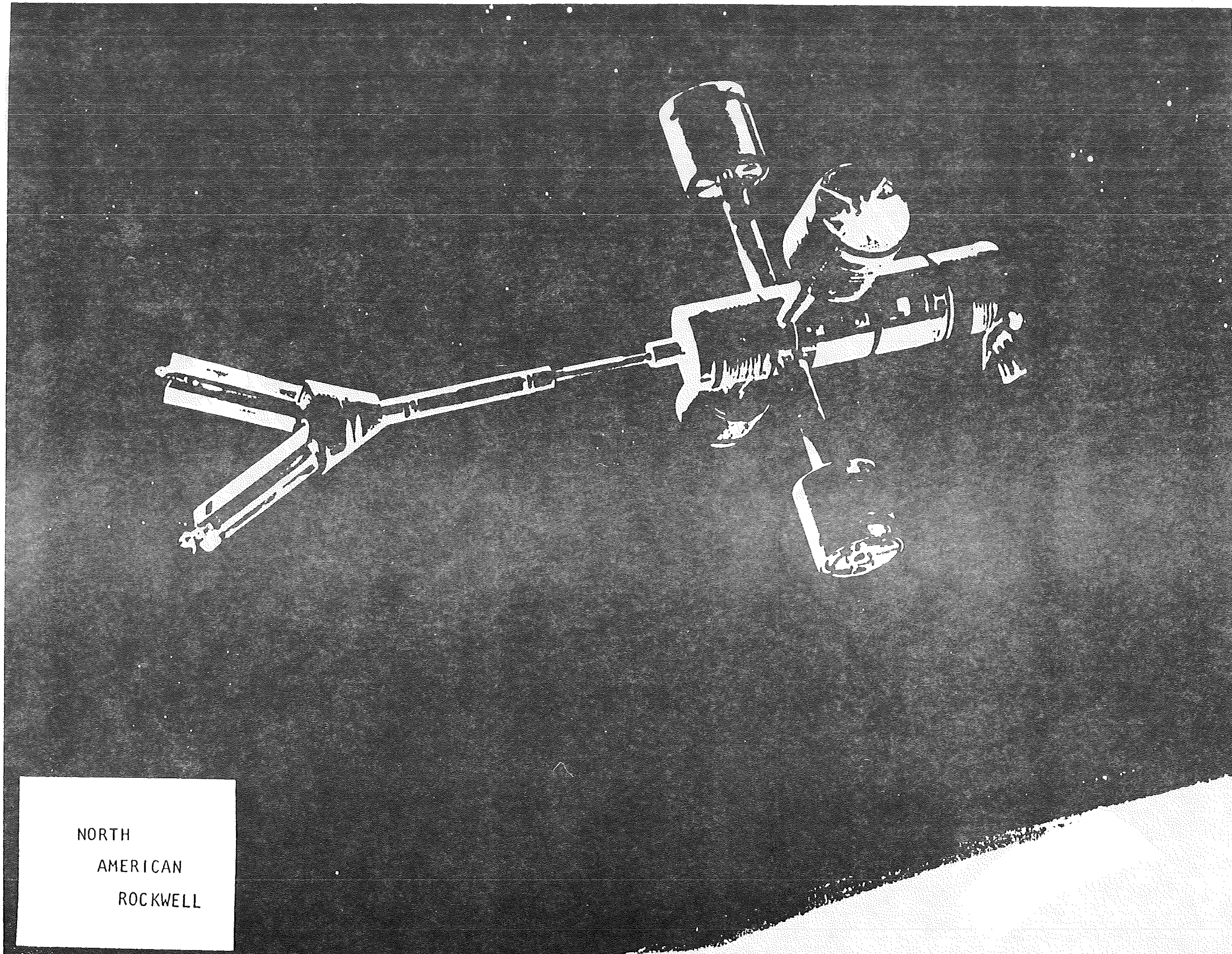


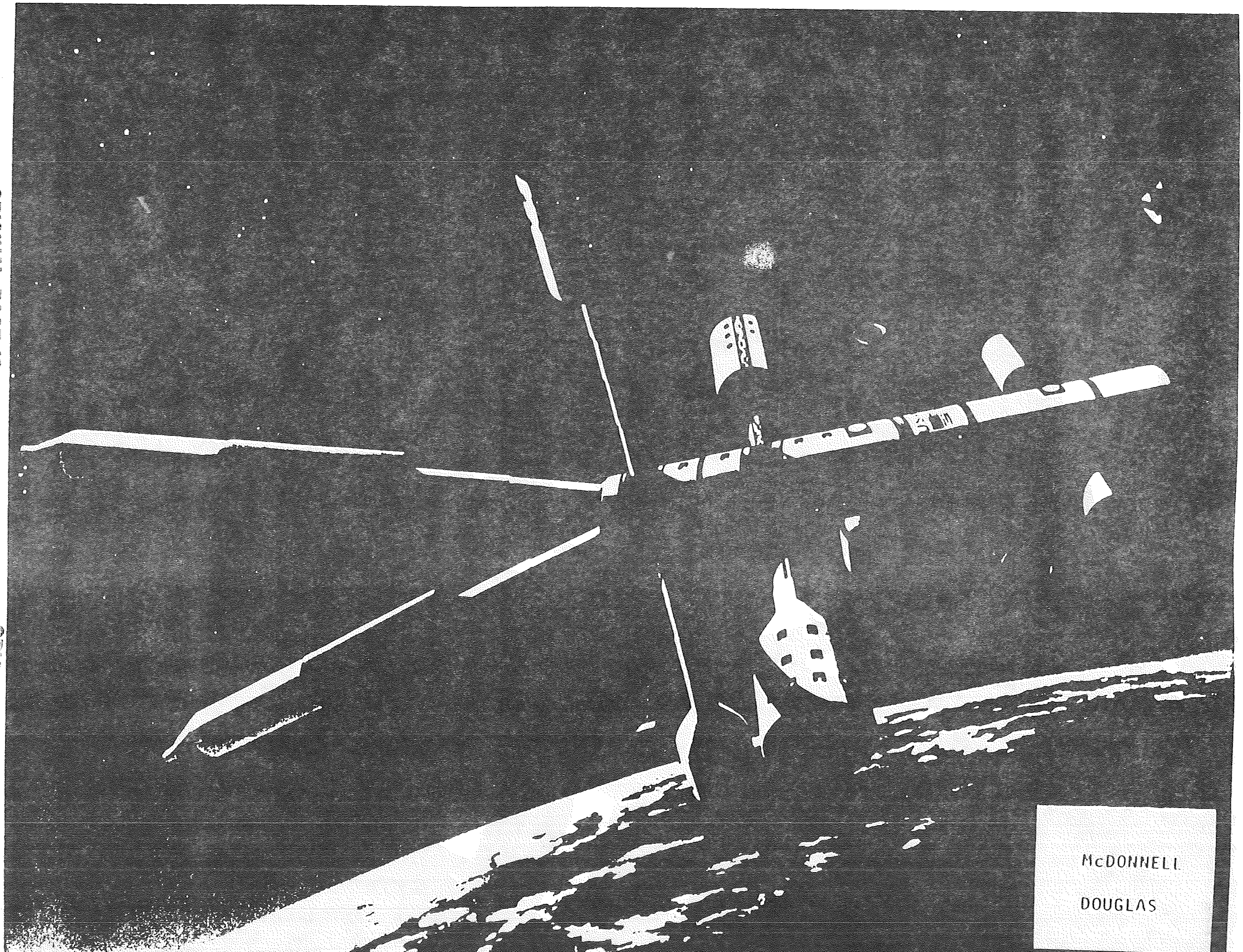


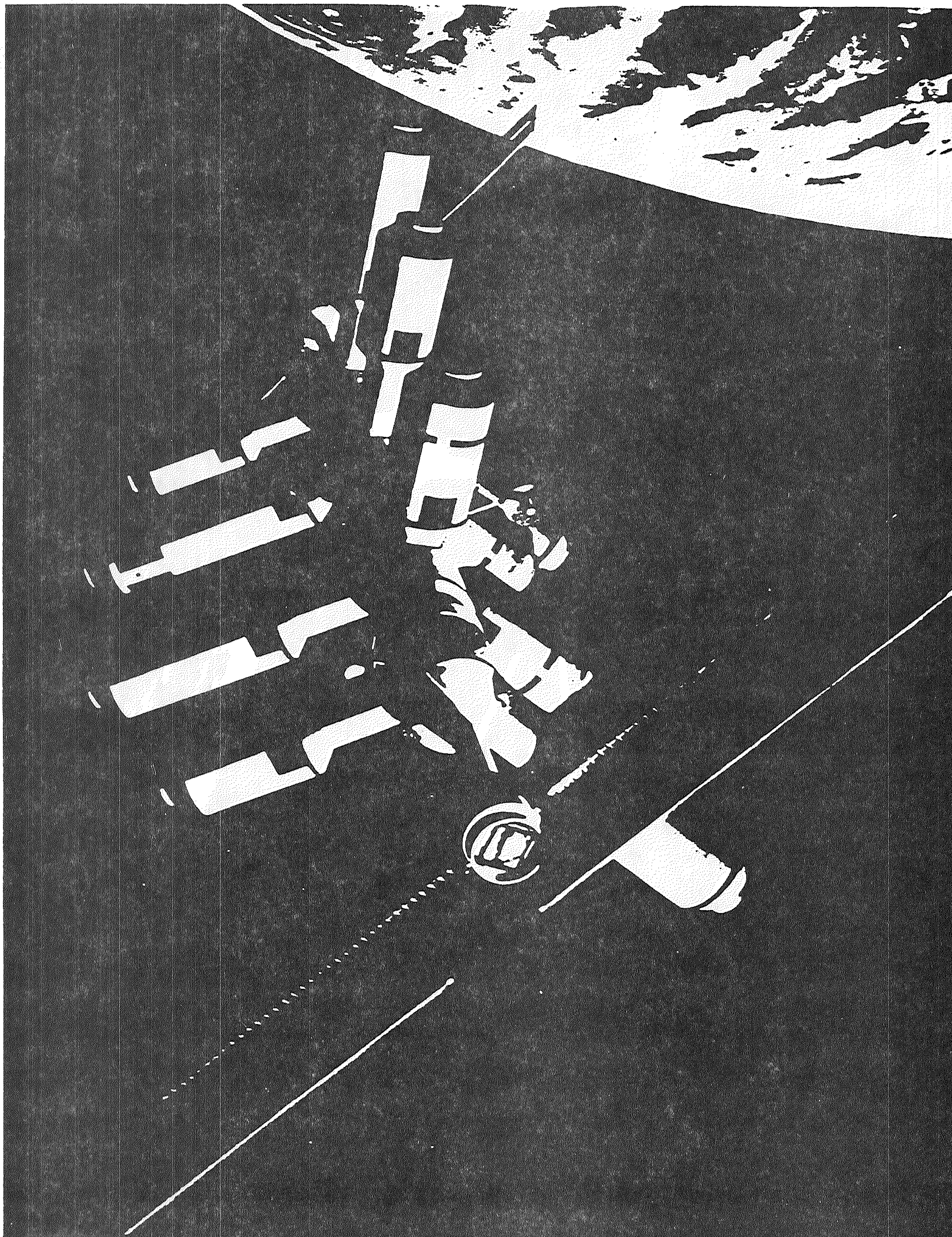

SPACE BASE CONCEPT

SA-S-65-2582

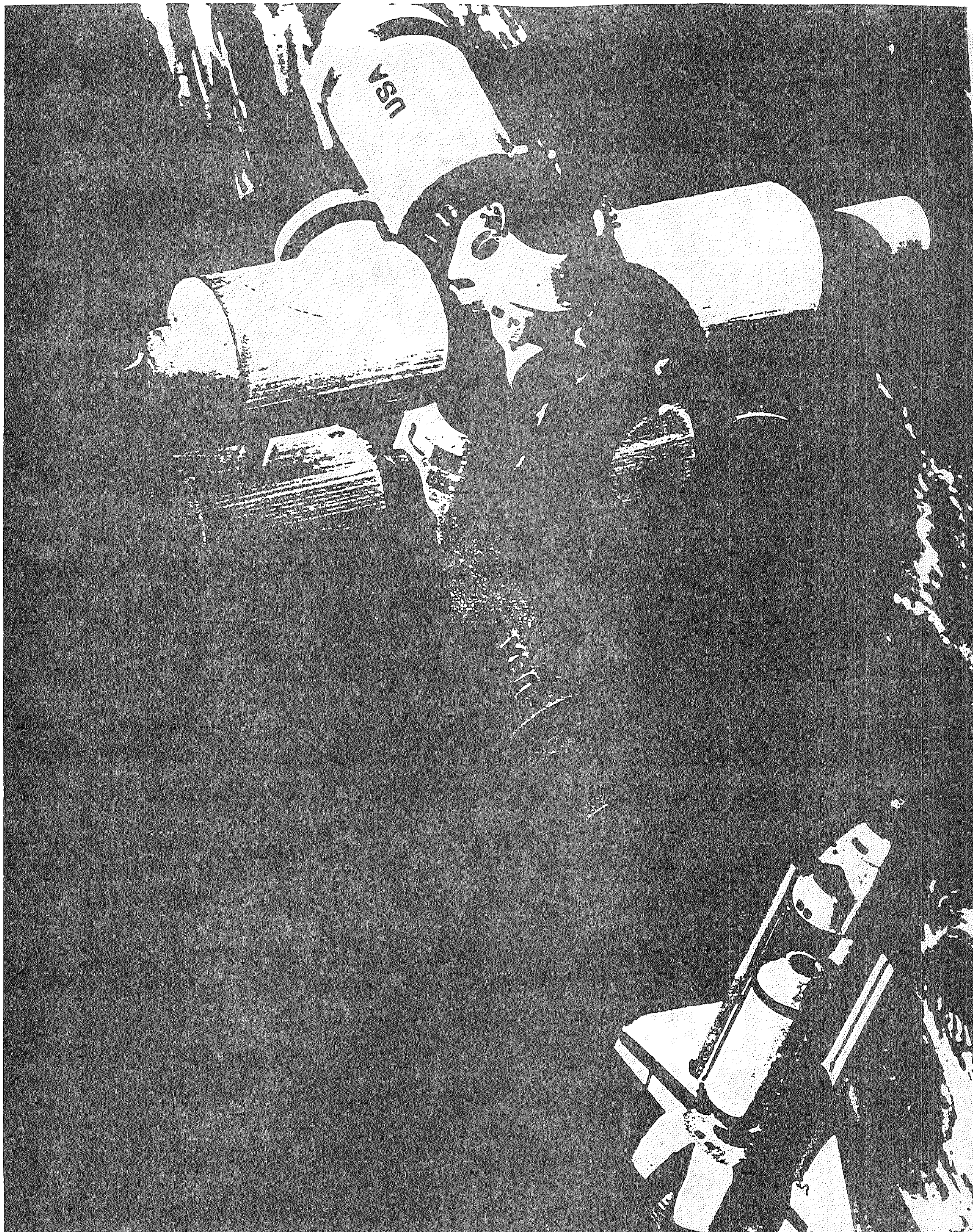


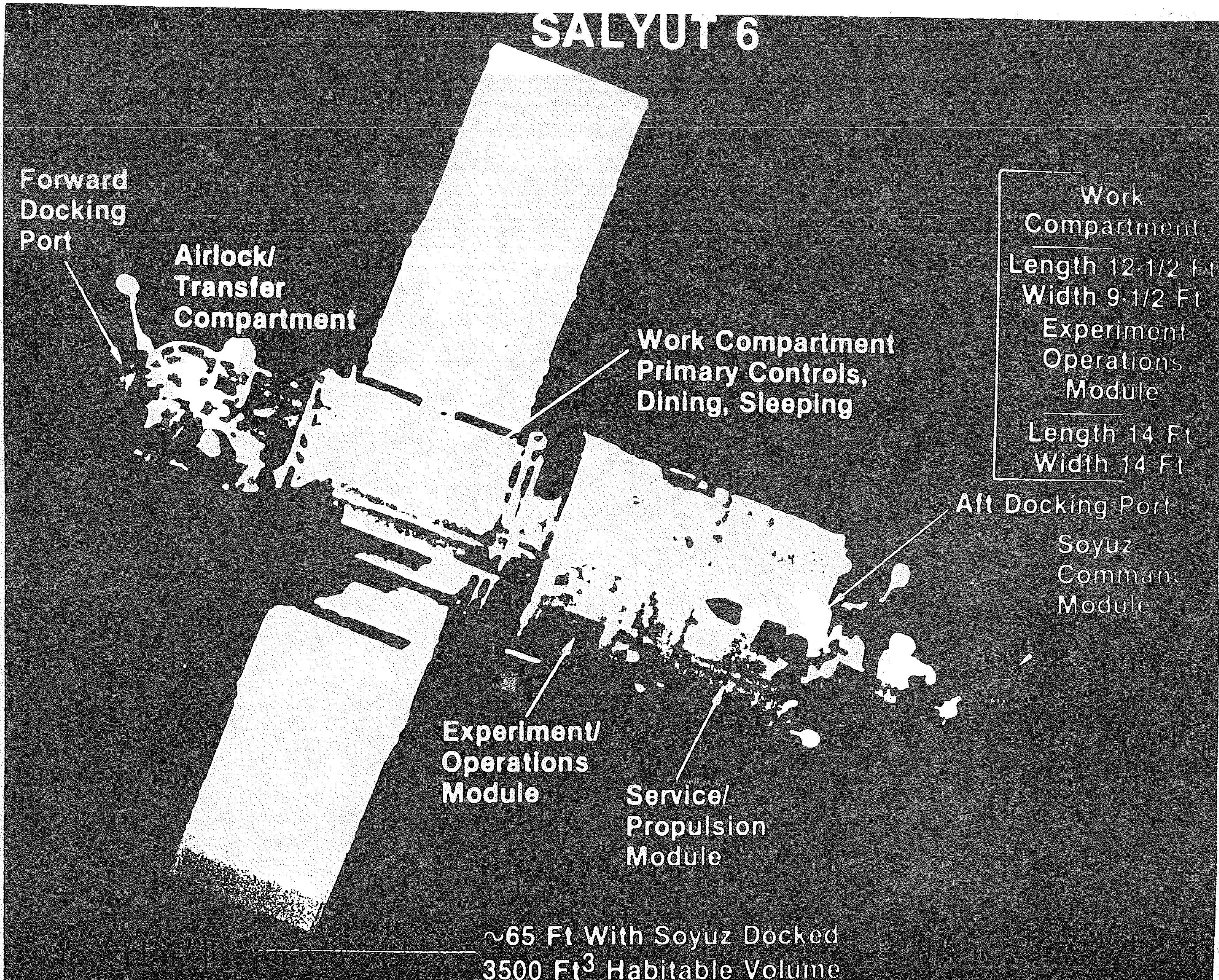

NORTH
AMERICAN
ROCKWELL


McDONNELL
DOUGLAS

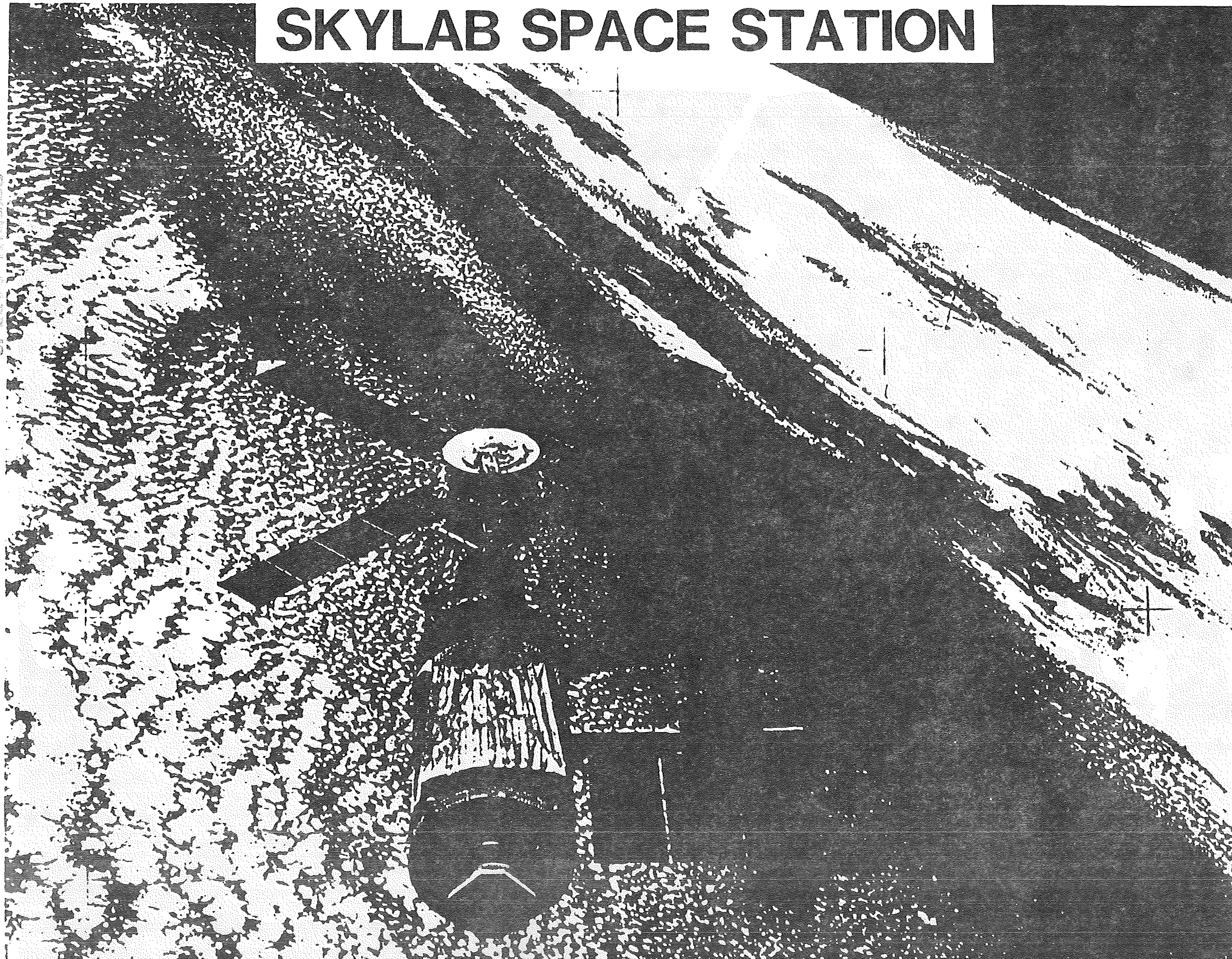


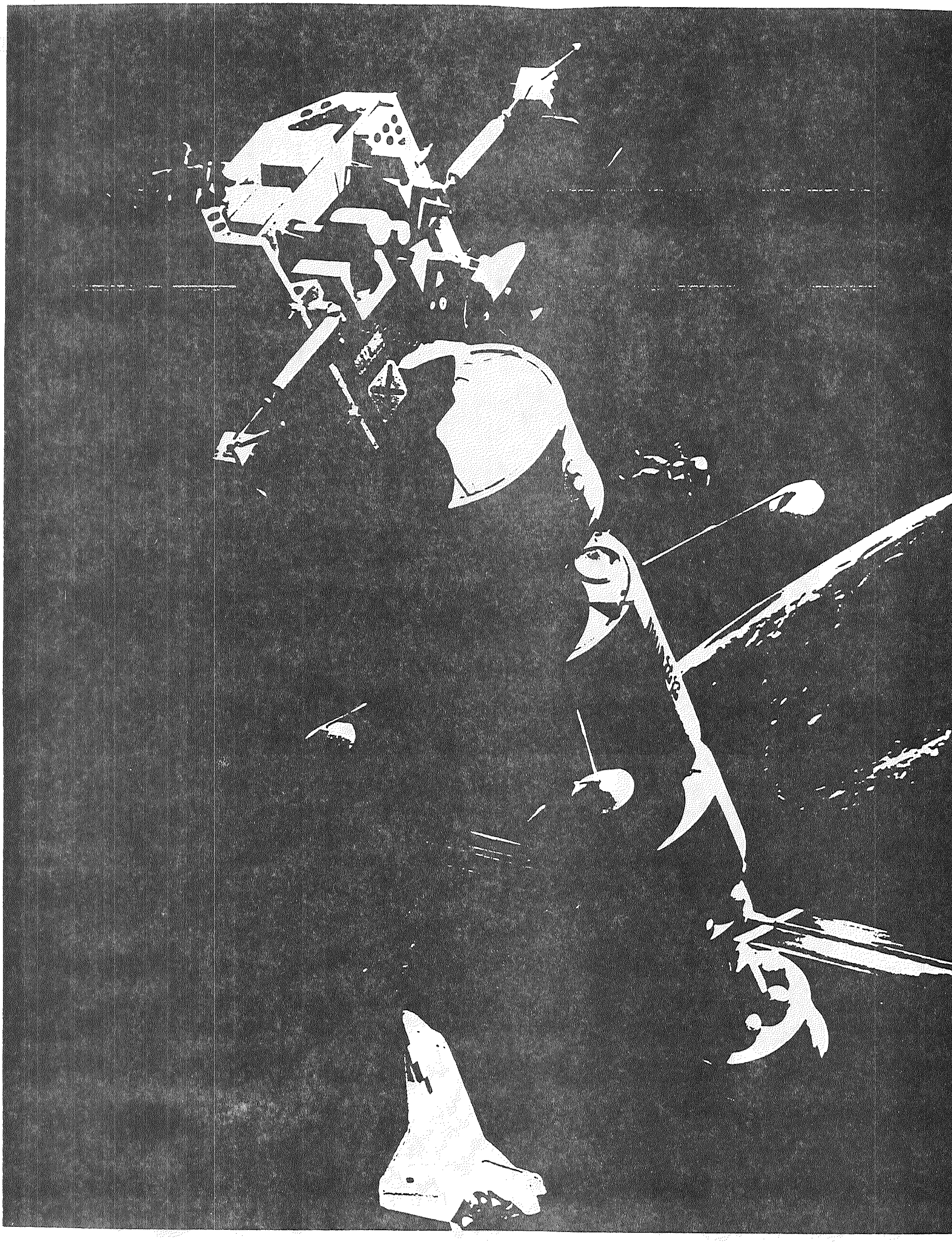
ORIGINAL PAGE IS
OF POOR QUALITY


USA


SALYUT 6
Forward Docking Port
Airlock/ Transfer Compartment
Work Compartment Primary Controls, Dining, Sleeping
Work Compartment
Length 12-1/2 Ft
Width 9-1/2 Ft
Experiment Operations Module
Length 14 Ft
Width 14 Ft
Aft Docking Port
Soyuz Command Module
Experiment/ Operations Module
Service/ Propulsion Module
~65 Ft With Soyuz Docked
3500 Ft3 Habitable Volume

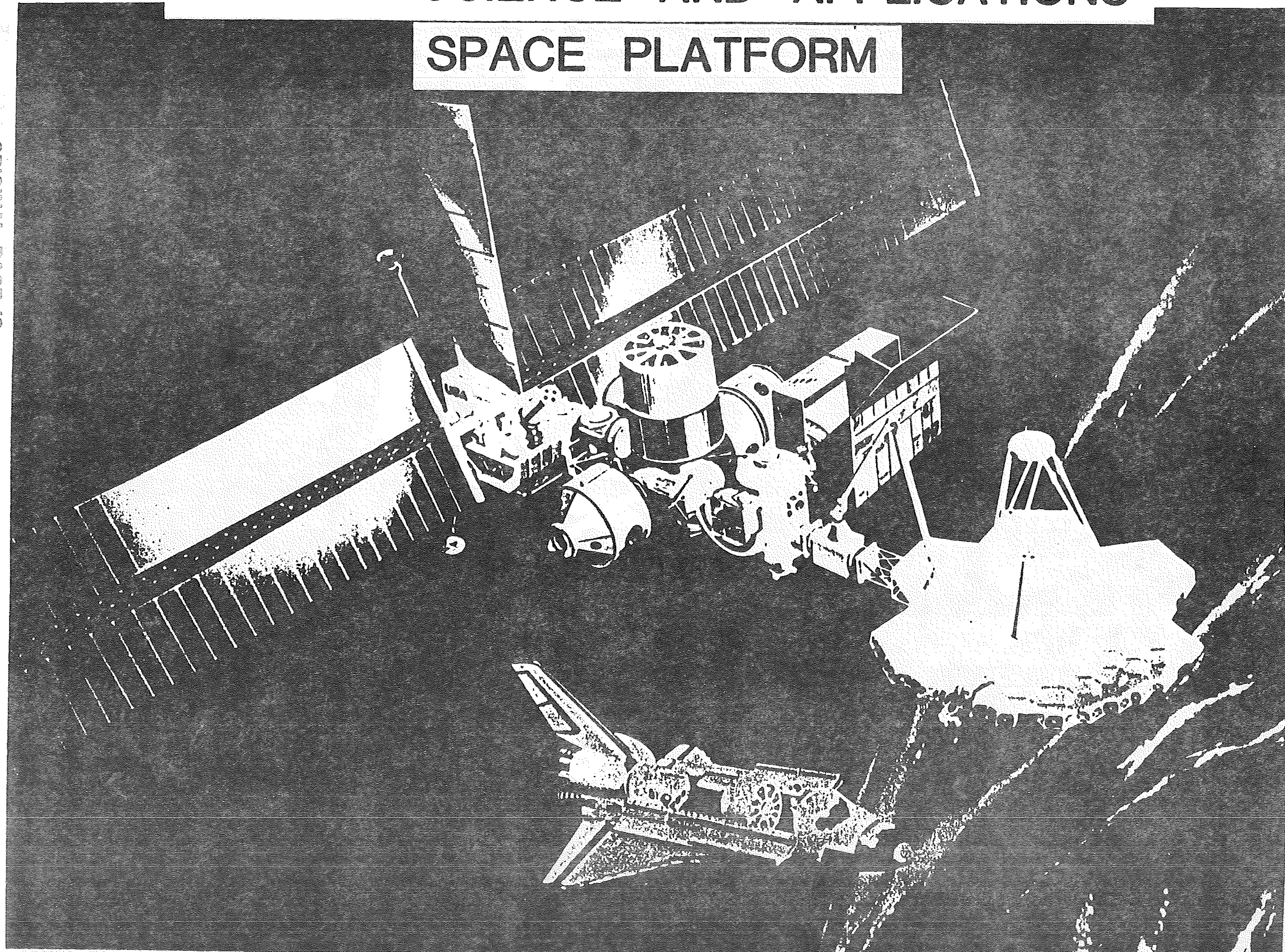
SKYLAB SPACE STATION





MANNED SCIENCE AND APPLICATIONS

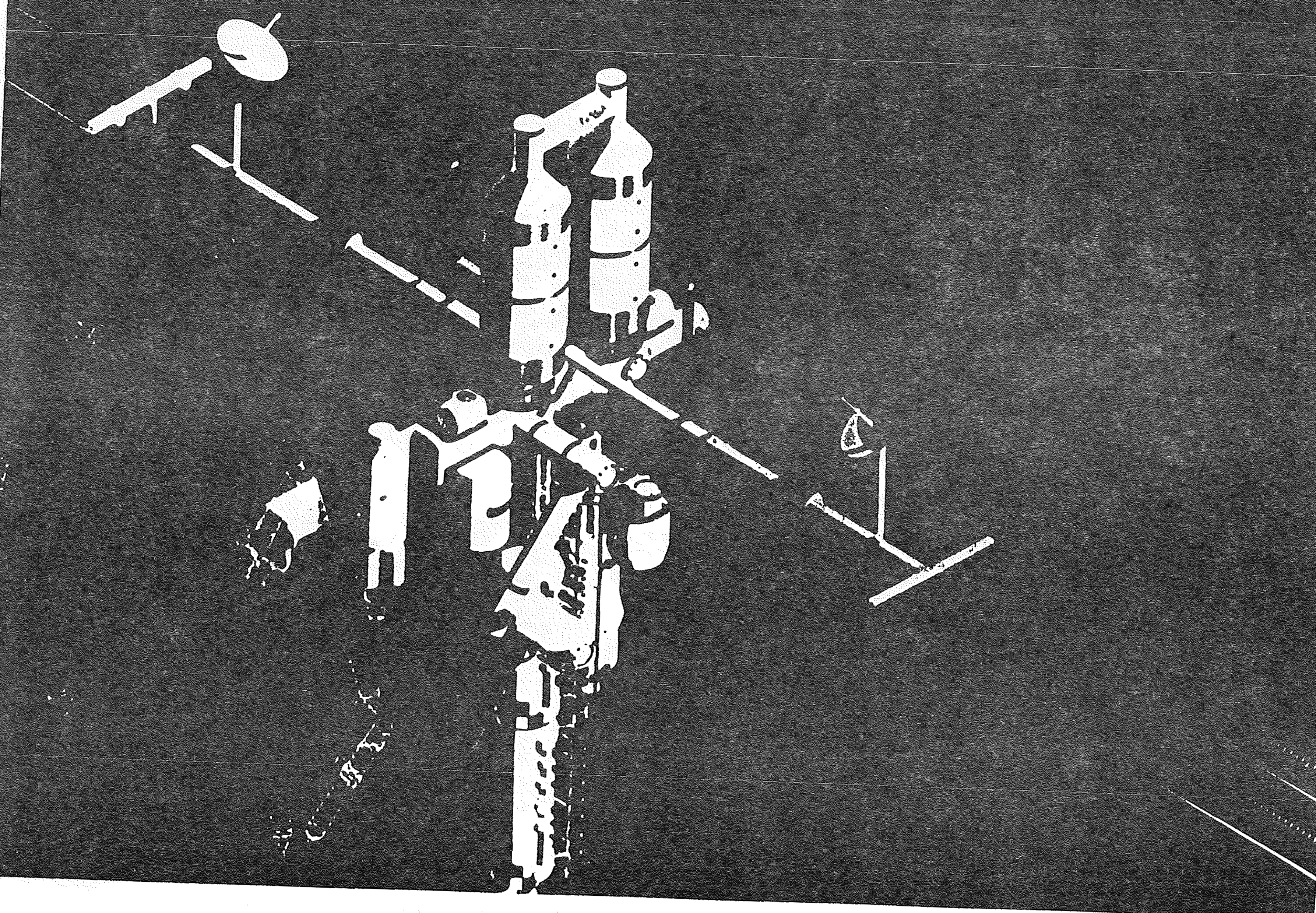
SPACE PLATFORM



NASA

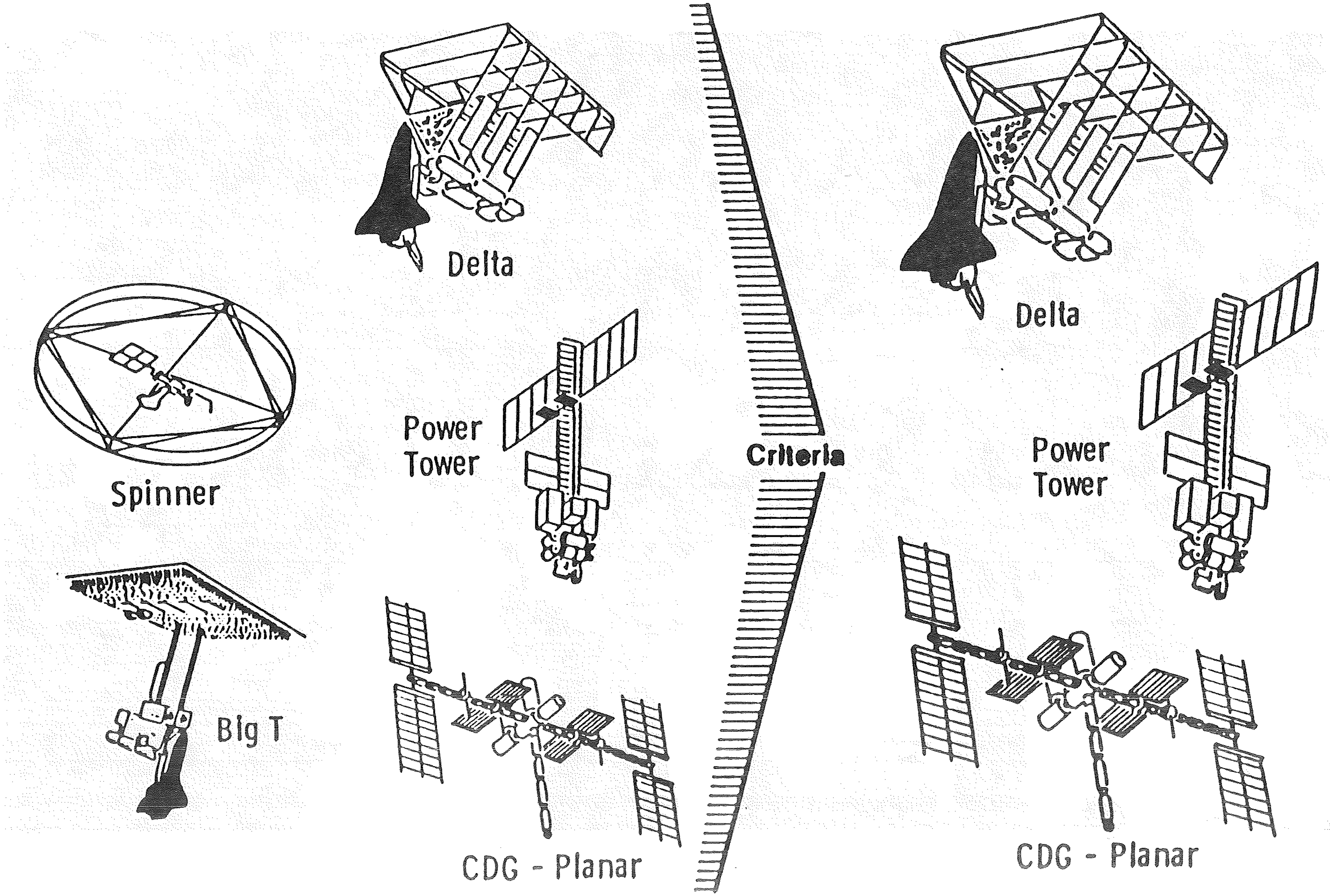
Evolutionary Growth

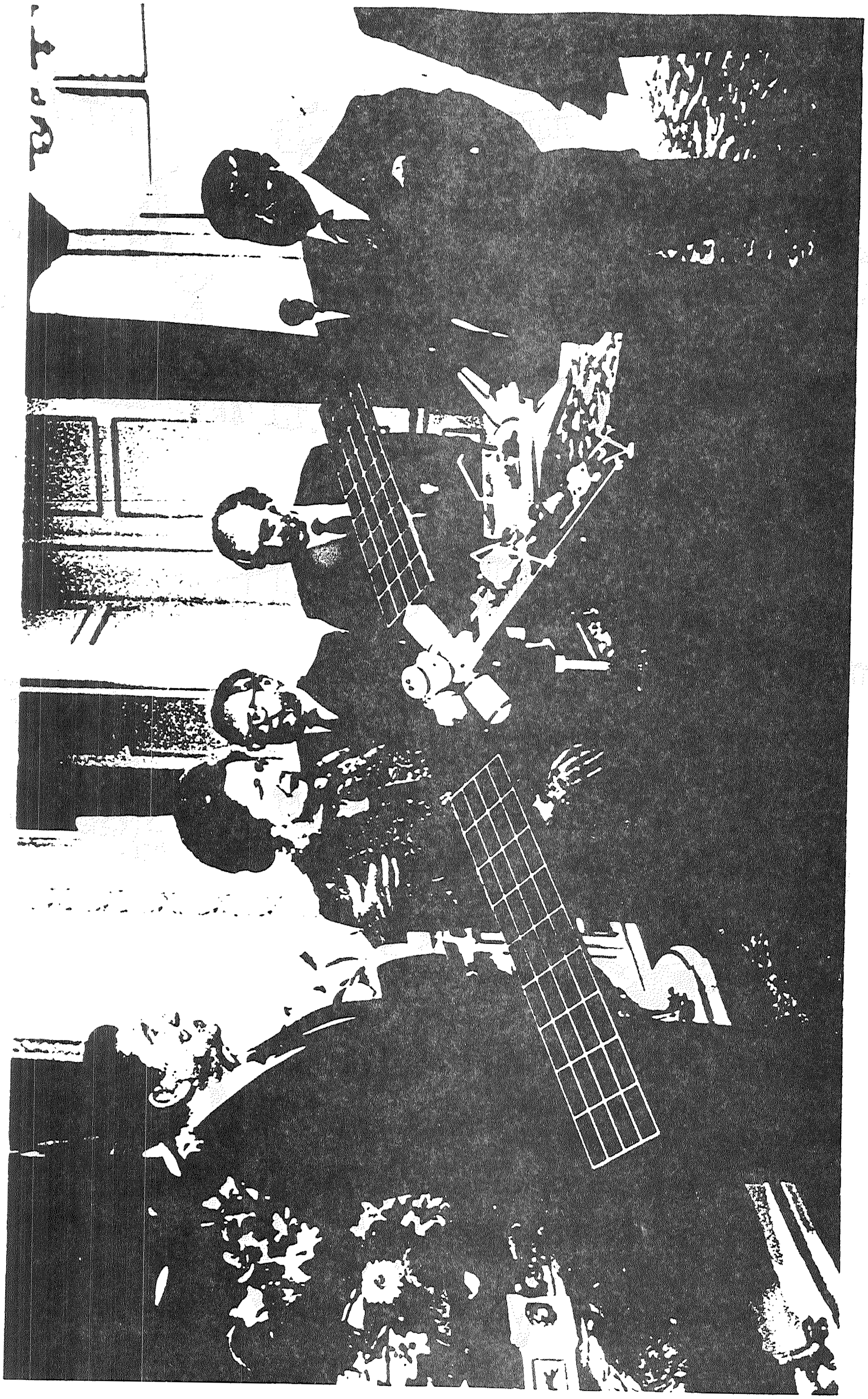
SOC

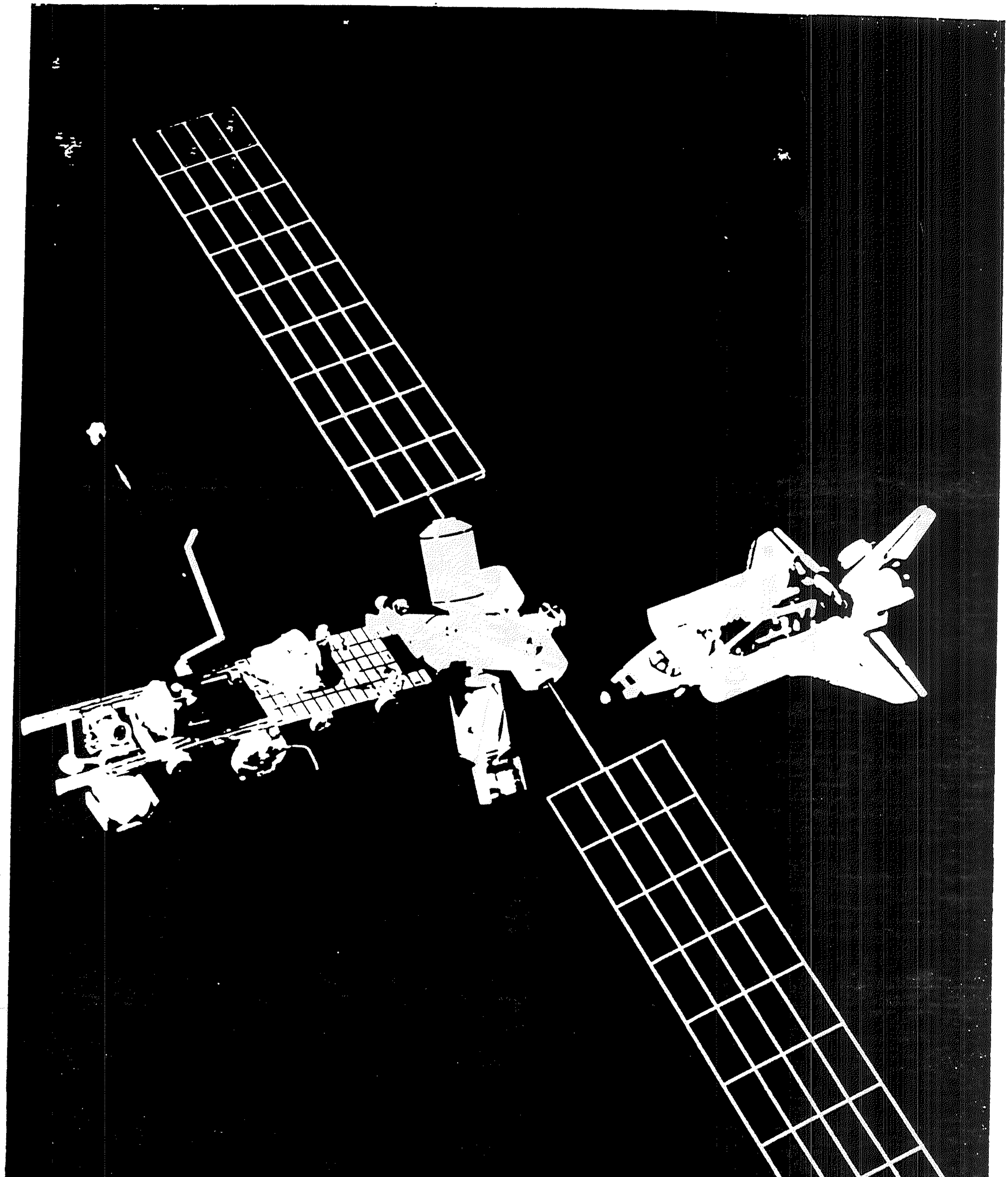


CONFIGURATION CONCEPT OPTIONS (SKUNK WORKS)

5 Candidate Concepts | **3 Chosen for Detailed Study**



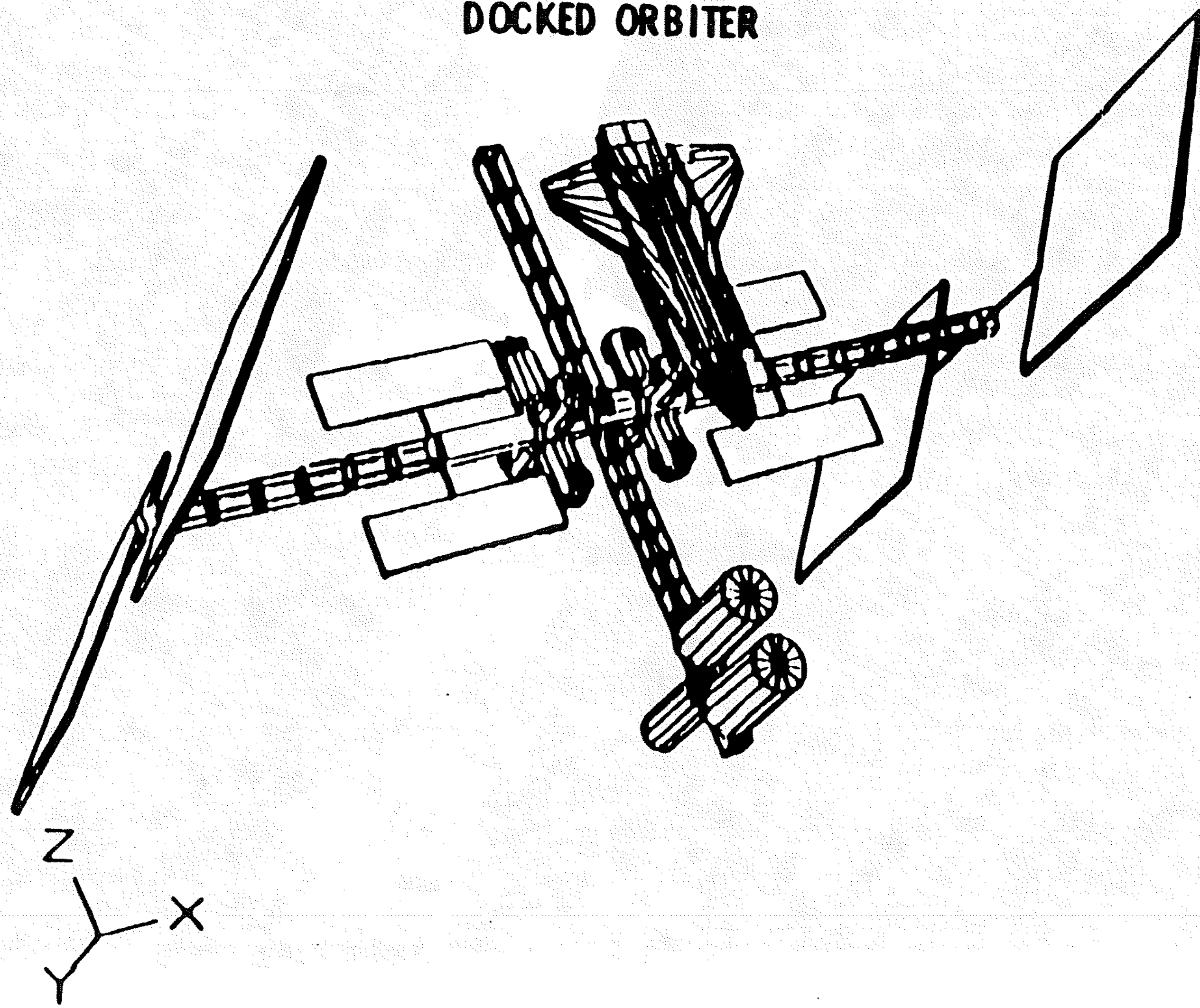


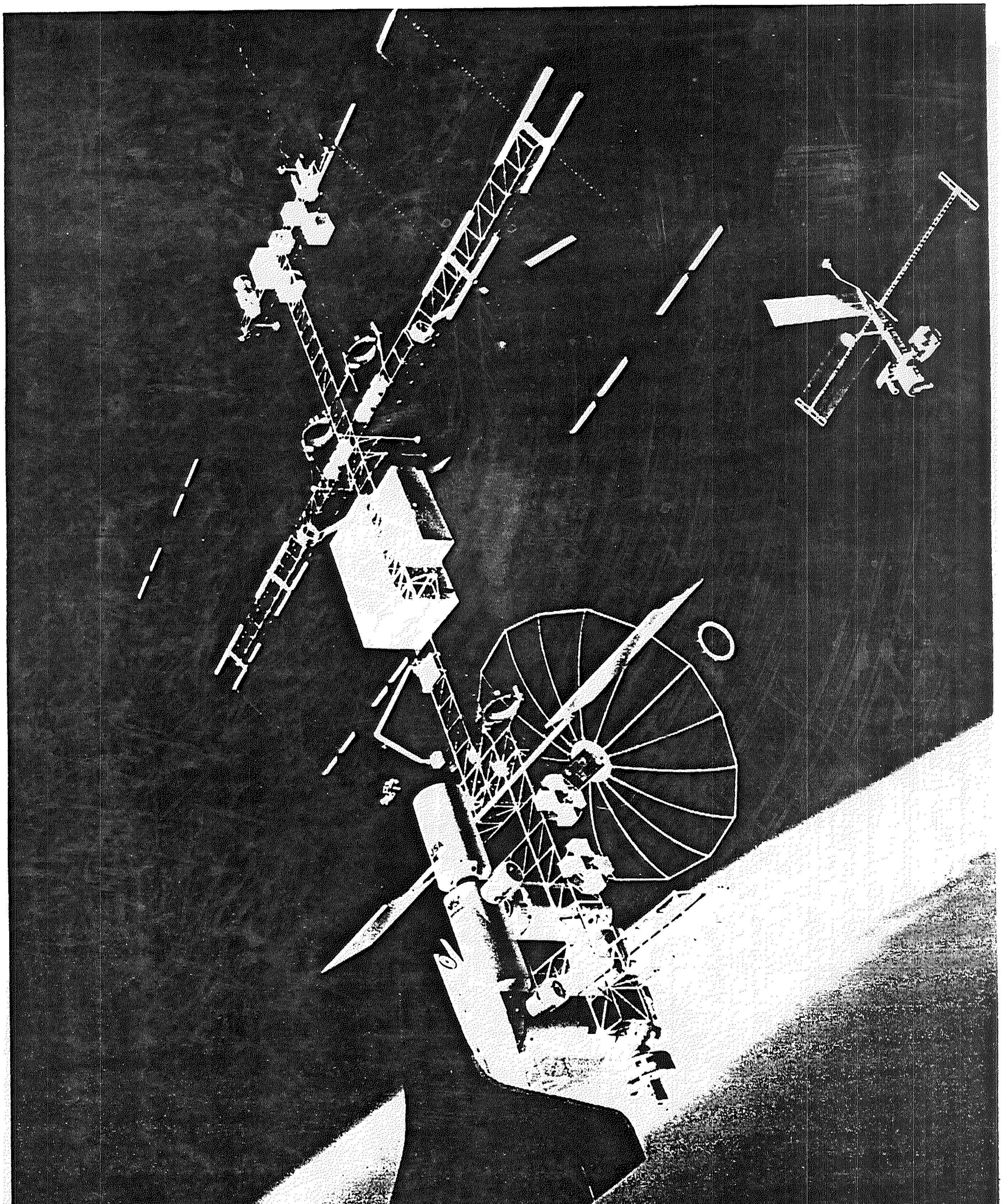


NASA
L-84-1443

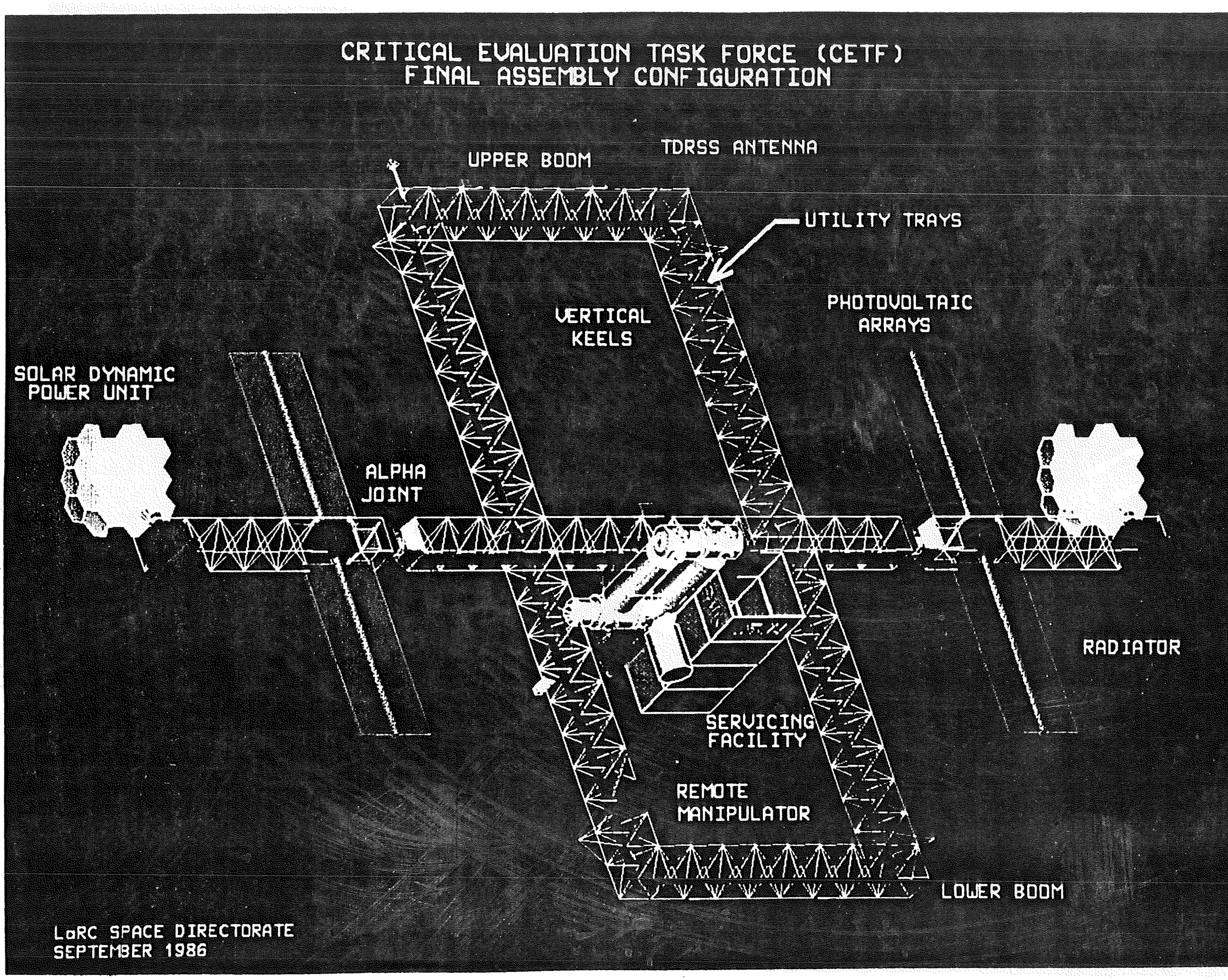
CDG - AXIAL RADIAL BASELINE

GROWTH
β = β max = 52°
DOCKED ORBITER

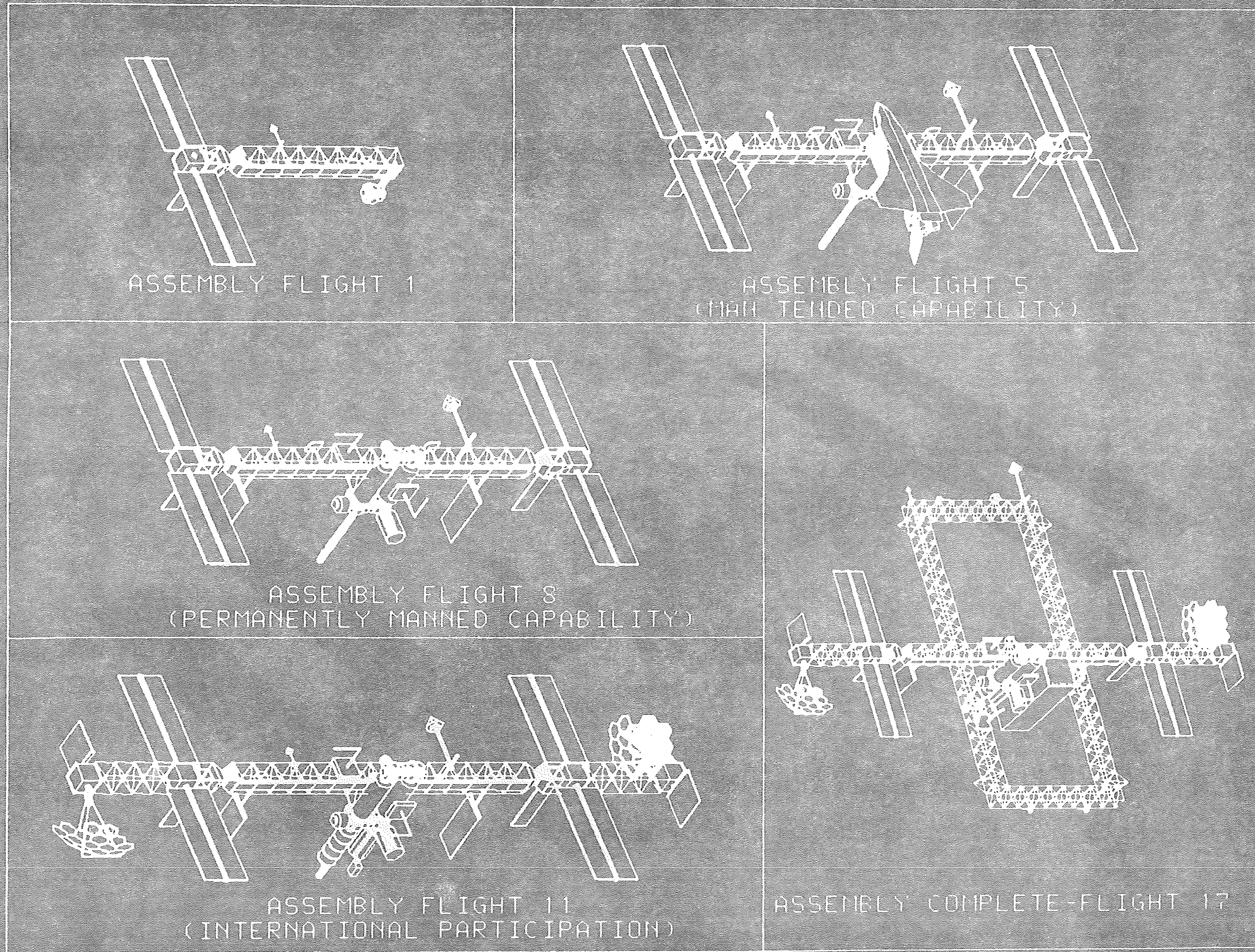


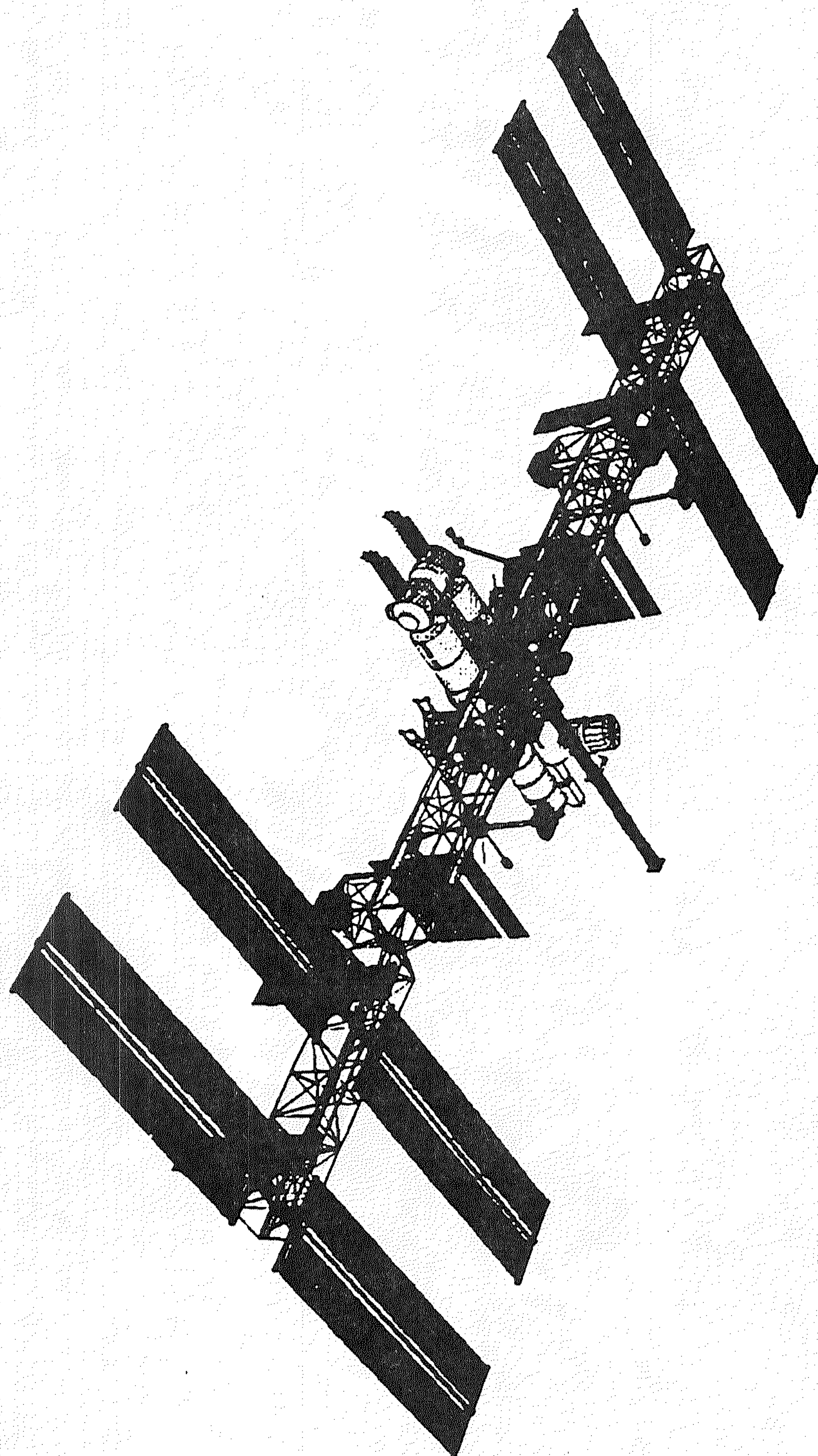


ORIGINAL PAGE IS
OF POOR QUALITY

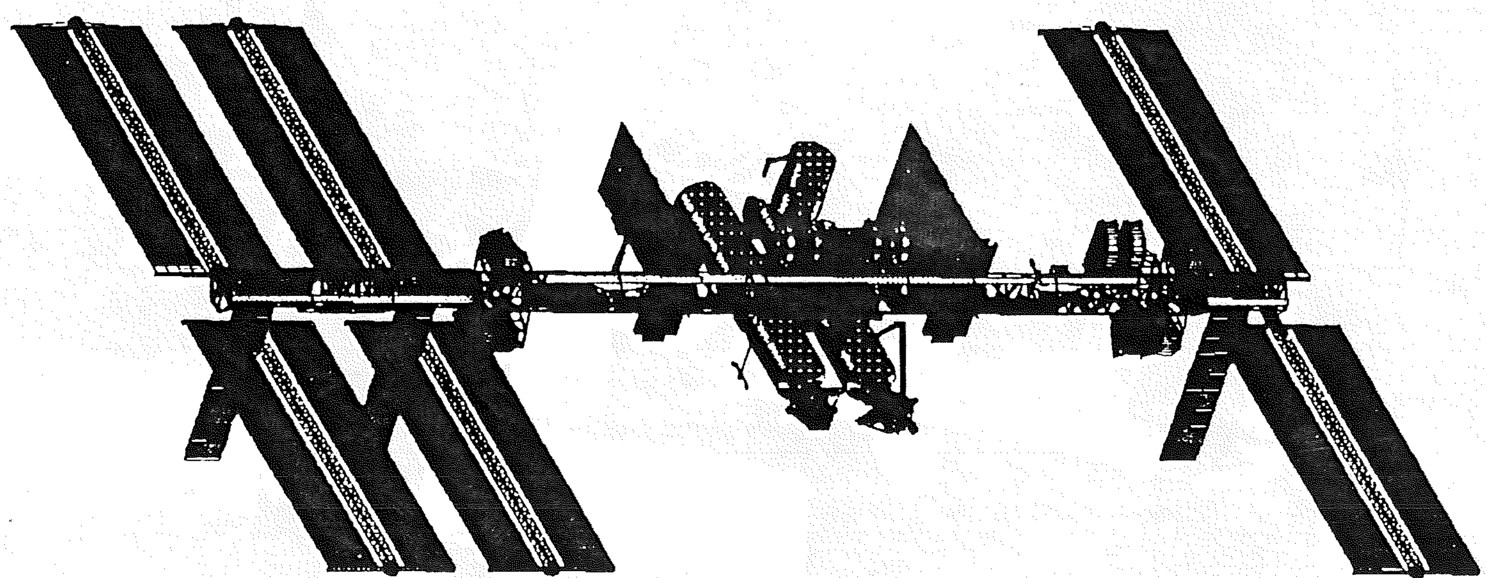

CRITICAL EVALUATION TASK FORCE (CETF)
FINAL ASSEMBLY CONFIGURATION
UPPER BOOM
TDRSS ANTENNA
UTILITY TRAYS
VERTICAL KEELS
PHOTOVOLTAIC ARRAYS
SOLAR DYNAMIC POWER UNIT
ALPHA JOINT
RADIATOR
SERVICING FACILITY
REMOTE MANIPULATOR
LOWER BOOM
LaRC SPACE DIRECTORATE
SEPTEMBER 1986

ASSEMBLY SEQUENCE HIGHLIGHTS

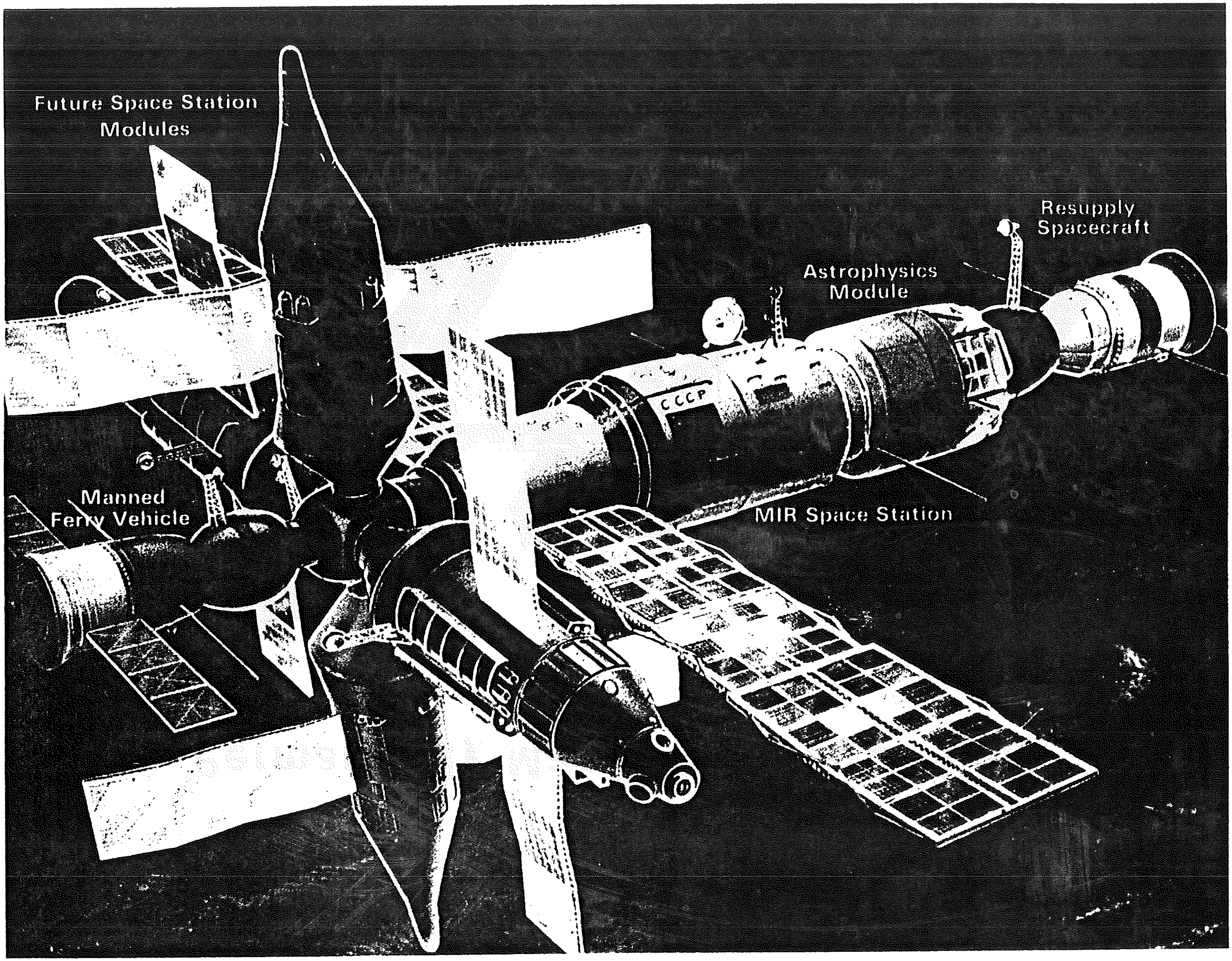




Permanently Manned Configuration

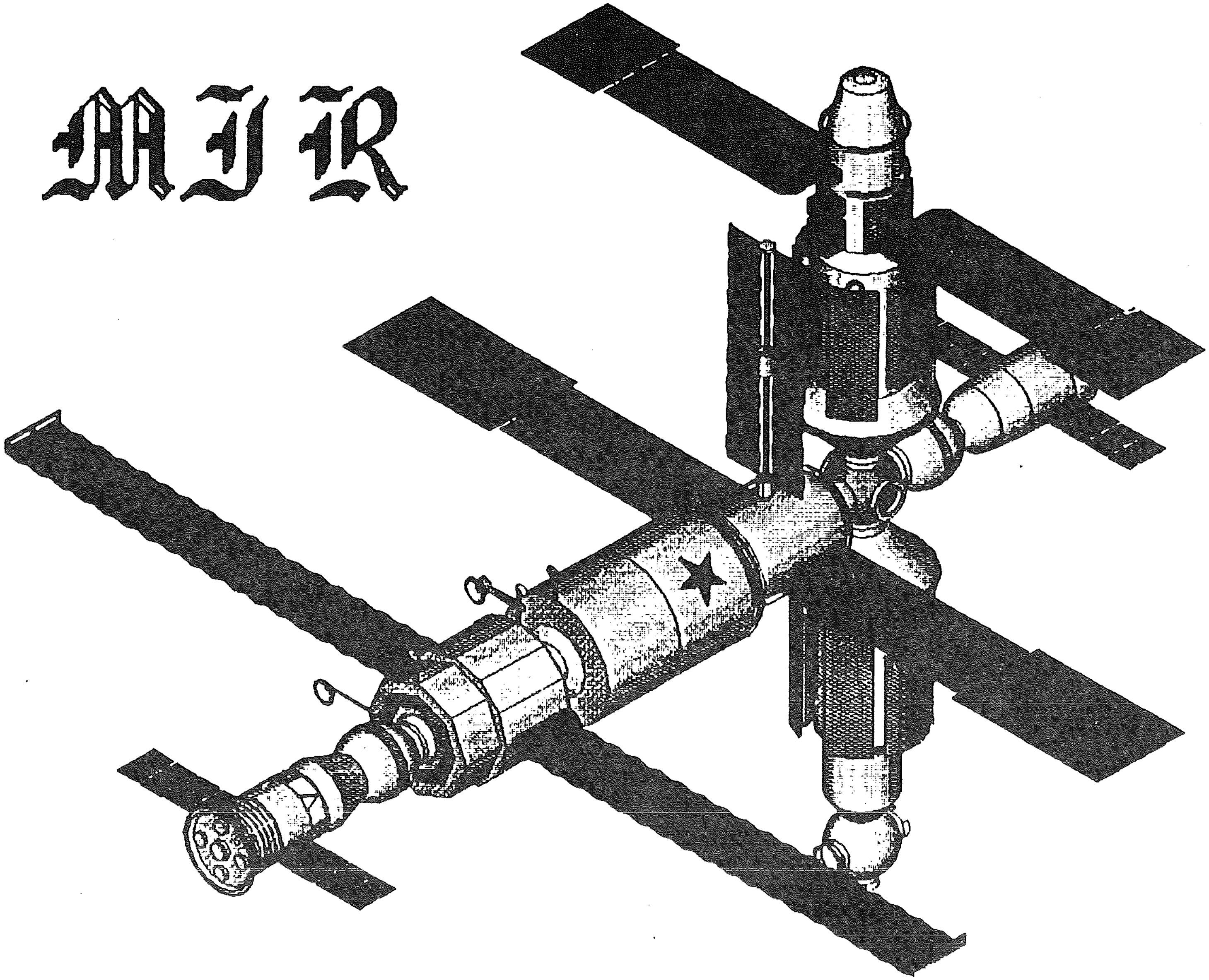


LaRC SSFO 4/25/91



Future Space Station
Modules
Resupply
Spacecraft
Astrophysics
Module
CCCP
Manned
Ferry Vehicle
MIR Space Station

MIR



ADVANCED STUDIES PROGRAM OVERVIEW

SPACE STATION EVOLUTION BEYOND THE BASELINE - 1991

AUGUST 7, 1991

Peter R. Ahlf
NASA HQ
Space Station Engineering

OBJECTIVES

- Develop evolution requirements & feasible evolution paths
- Identify design provisions that enable evolution of baseline systems
- Identify technologies that enable/enhance operations and evolution
- Perform early programmatic planning for development programs beyond the baseline
- Include international partner participation in evolution

PAGE 238 INTENTIONALLY BLANK

PRECEDING PAGE BLANK NOT FILMED

APPROACH

- Evolution responsibility assigned to Level I, Space Station Engineering
- LaRC provides technical oversight and integration
- Evolution Working Group established to provide support from work packages and field centers
- Studies program provides primary interface between SSF and other agency advanced programs such as Space Exploration Initiative
- International Evolution Working Group provides forum for participation by the international partners (MOU agreement)

LEVEL 1 ENGINEERING ORGANIZATION

Space Station Engineering (MT)

Space Station Freedom Office (LaRC)

- Advanced Systems Studies
- Level I System Engineering and Analysis Support

Configuration Management Office (MT-1)

- Level I Configuration Management Support
- MIC/VITS Support

System Engineering and Analysis (MTE)

- Systems Req., Anal. & Definition
- Systems Engr. Studies
- Tech.Assessment of Change Requests
- Independent Assess. of Flight & Ground Systems Performance

System Development (MTD)

- Req'ts Implem. Oversight
- Budget, Schedule, & Content
- Oversight and Assessment
- Development Status Reporting
- Development Assess.
- Level I TMIS Support

Advanced Programs (MTE)

- Advanced Planning
- Advanced System Studies
- Technology Req'ts Definition & Assess.
- Advanced Dev.
- Commercial Dev.
- International Evolution

ADVANCED STUDIES PROGRAM ORGANIZATION

NASA HQ
- Management & Budget
- Interface w/related programs

INTERNATIONAL EVOLUTION WORKING GROUP
- MOU Created
- U.S., ESA, NASDA, & CSA

NASA LaRC
- Technical Oversight, Integration, & Analysis
- Chairs the Evolution Working Group
- Configuration & Concept Development

EVOLUTION WORKING GROUP
- Independent Advisory Group
- KSC, JSC, LeRC, ARC, MSFC, JPL, GSFC, and SSFPO

KSC | JSC | LeRC | ARC | MSFC

NASA CENTER SUPPORT AREAS

NASA KSC
- Assembly & Processing Operations

NASA LeRC
- Electrical Power System Evolution
- Cryogenic Operations

NASA ARC
- DMS Evolution

NASA LaRC
- Technical Integration

NASA JSC
- Distributed Systems Evolution Analysis
- Crew Operations

NASA MSFC
- Modules / Internal Systems Evolution

WORK BREAKDOWN

TASK AREAS

Long Term Utilization

Distributed Systems Evolution

Concepts and Configurations

Operations Feasibility

PRODUCTS

Level 1 Growth Requirements

Reference Growth Paths

Technology Requirements

Early Programmatic Planning

NASA FREEDOM

SPACE STATION FREEDOM PROGRAM PHASES

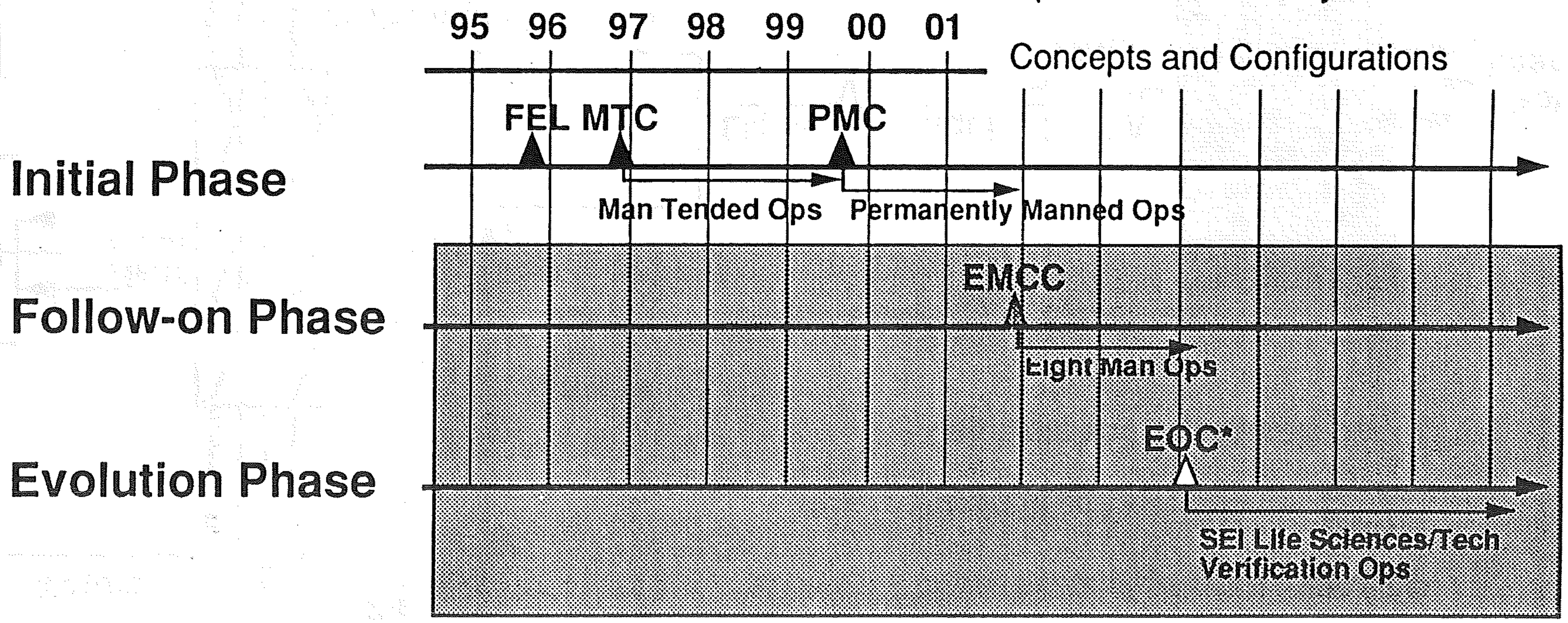
TASK AREAS

Long Term Utilization

Distributed Systems Evolution

Operations Feasibility

Concepts and Configurations



* Enhanced Operating Capability based on SSF Continued Development Plan

Milestones based on SEI POP 91-1 Planning Schedule

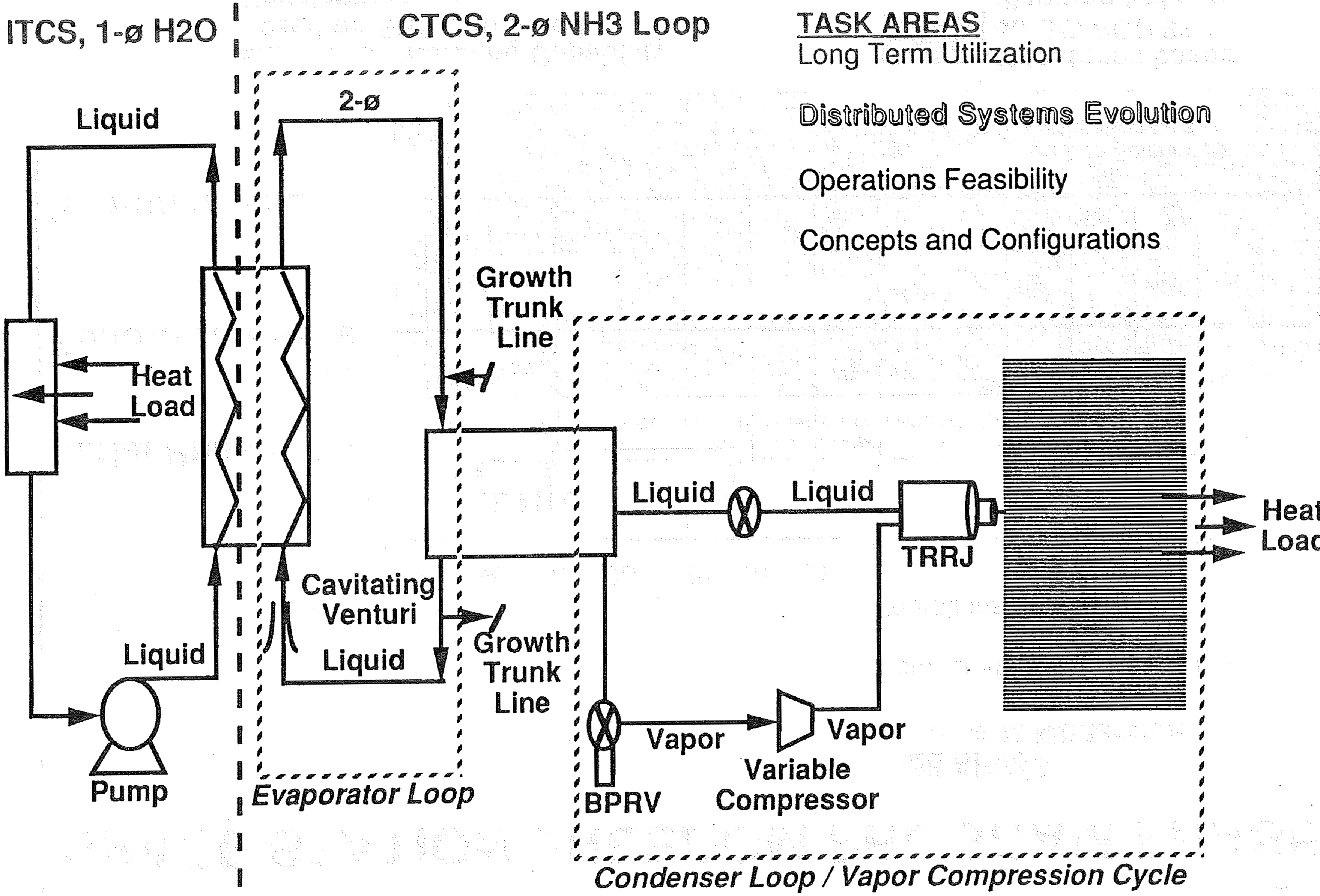
DISTRIBUTED SYSTEMS EVOLUTION

<u>TASK AREAS</u>
Long Term Utilization

Distributed Systems Evolution

Operations Feasibility

Concepts and Configurations



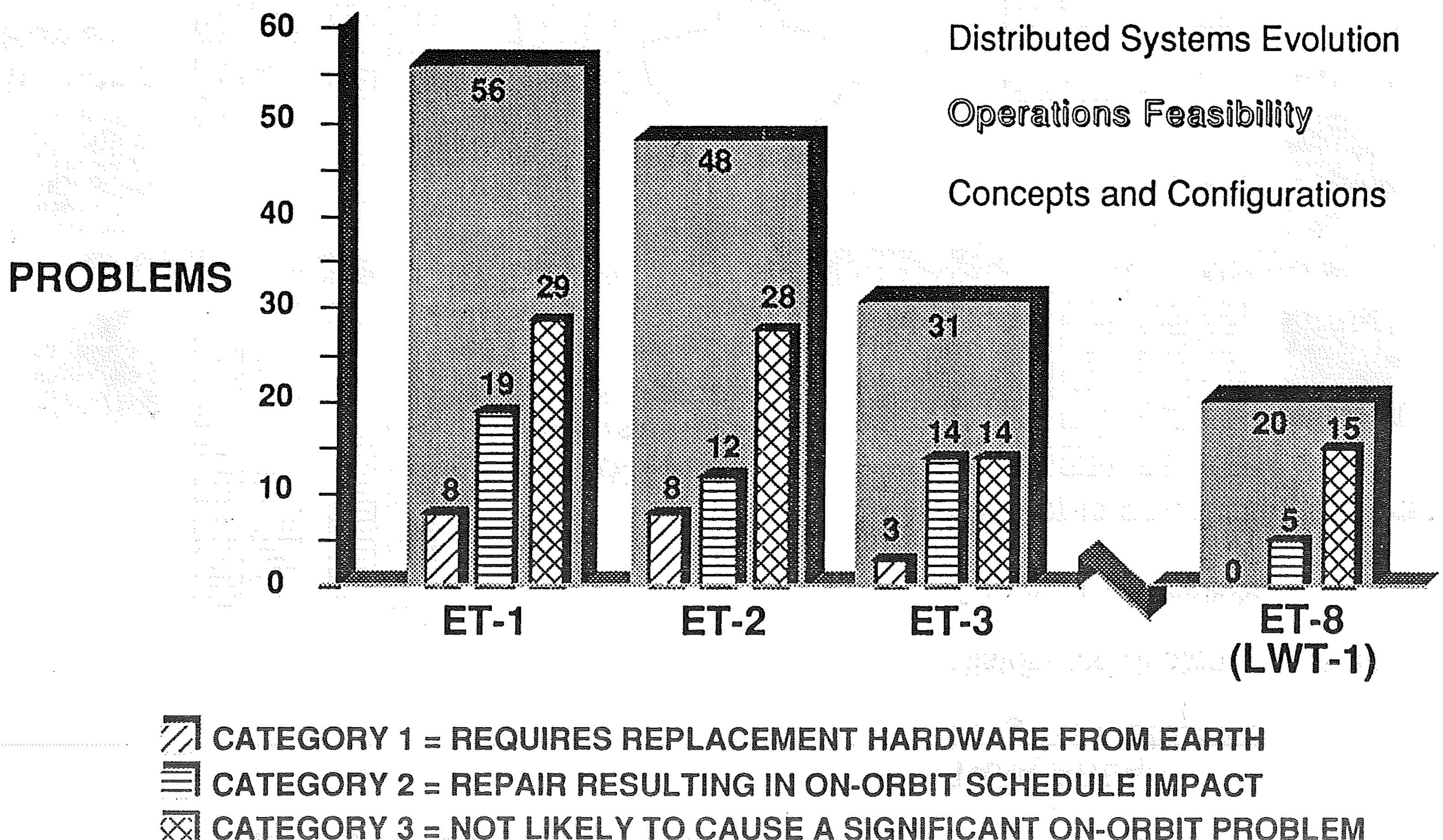
SHUTTLE ET MATING ANALOGY TO ON-ORBIT TANK MATING

TASK AREAS
Long Term Utilization

Distributed Systems Evolution

Operations Feasibility

Concepts and Configurations



REFERENCE GROWTH CONCEPT

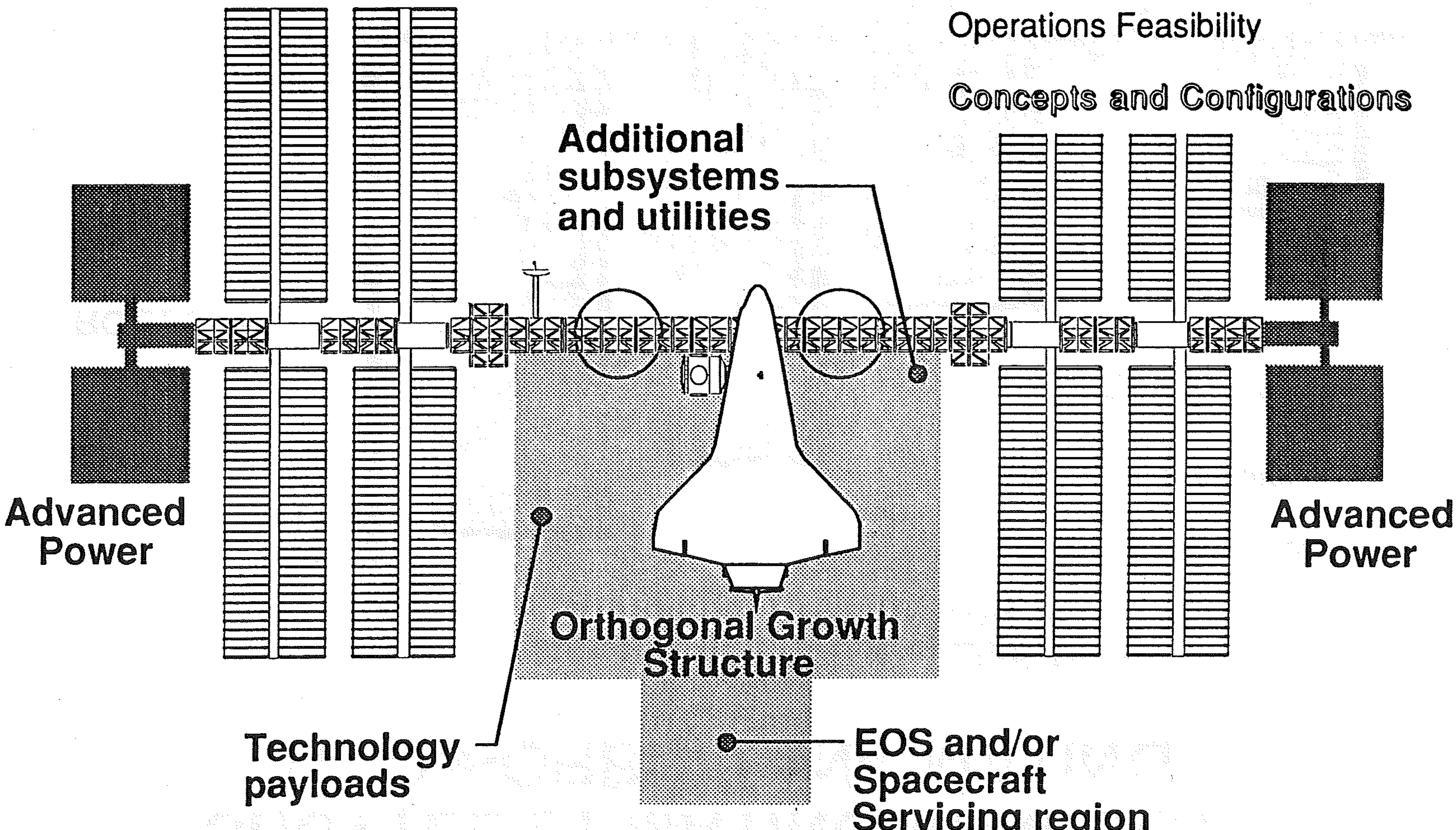
TASK AREAS

Long Term Utilization

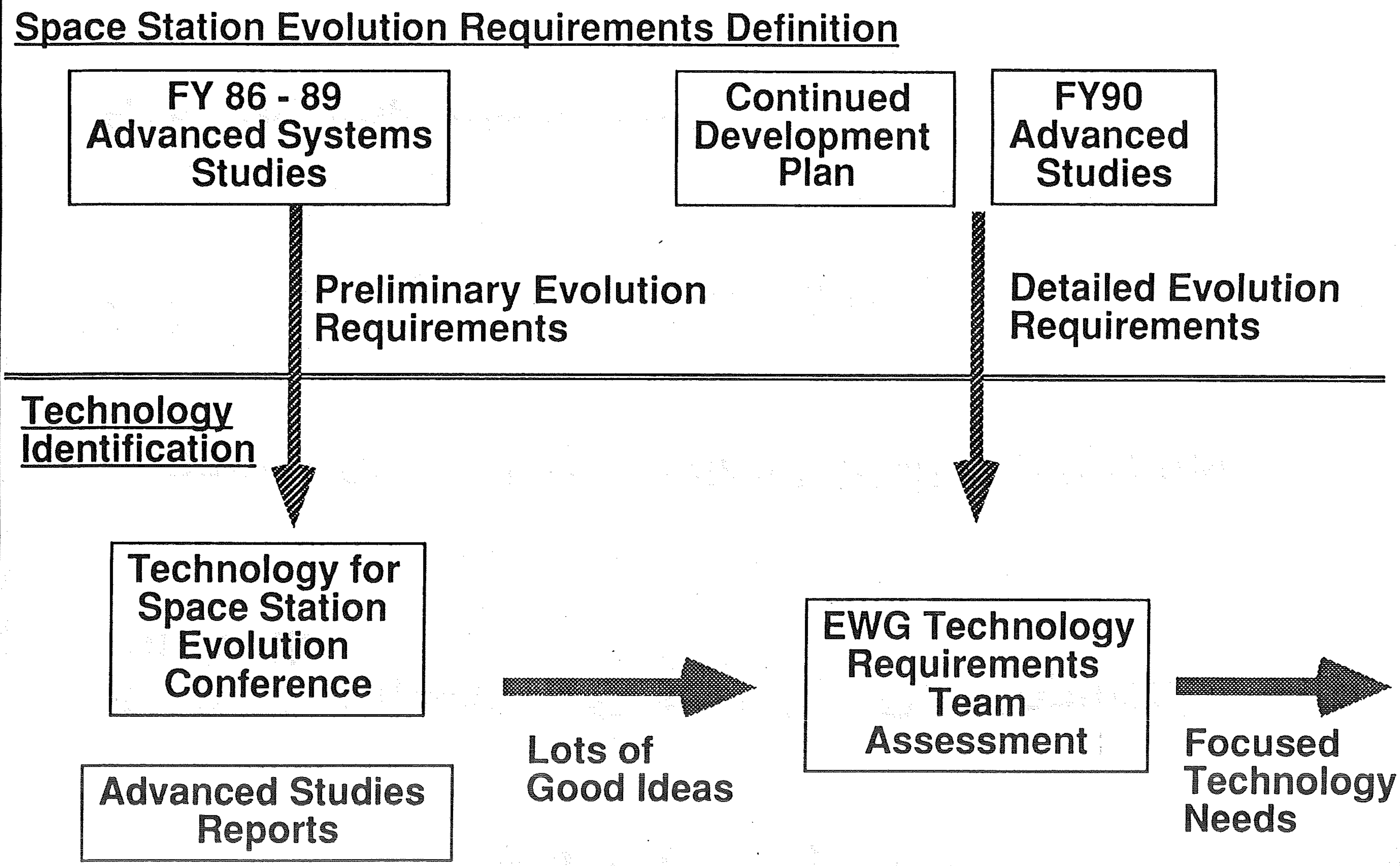
Distributed Systems Evolution

Operations Feasibility

Concepts and Configurations



TECHNOLOGY ASSESSMENT PROCESS



TECHNOLOGY DRIVERS

- Supports expanded Research & Development utilization
- Supports Space Exploration Initiative utilization
- Enhances crew safety / productivity
- Reduces operations cost

SSF TECHNOLOGY PRIORITIES

- Vehicle Health Management
- Crew Training Systems
- Advanced Heat Rejection
- High Efficiency Space Power Systems
- Water Recovery & Management
- Robotics
- Advanced Extravehicular Mobility Unit
- Orbital Debris Protection
- Advanced Avionics Architectures

ACCOMPLISHMENTS

- Created a Continued Development Plan for Space Station Freedom
- Evaluated growth capability and limitations of the baseline design to a detailed subsystem level
- Developed and baselined evolution requirements in the Program Requirements Document
- Developed technology requirements for long term Space Station Freedom utilization

NEAR TERM DIRECTION

- Document a reference growth concept
- Advocate and implement critical scars in the baseline design
- Lay the groundwork for on-time technology availability

NASA
OSF

FREEDOM

Space Station Freedom Engineering Prototype Development

Space Station Freedom Evolution Beyond The Baseline

August 8, 1991

Alan Fernquist
Code MT
NASA, Headquarters

Engineering Prototype Development

Briefing Outline:

- Background
- Objective
- WBS Elements
- Summary

Engineering Prototype Development

Program Content Guided by a Series of Focused Studies

The content of the Advanced Development Program and subsequent Engineering Prototype Development activity has been guided by a series of focused studies. These studies Started with the report of the Advanced Development Task Force led by Ray Hook in 1988. An outline of issues relating to Automation, Data Systems and Telerobotics was projected for Space Station. Subsequent studies built upon and reaffirmed a focus on development and prototyping of Automation Technology for subsystem monitoring and problem diagnosis, Data System growth to accommodate more sophisticated automation, and use of Telerobotics technology to assist in the reduction of required EVA and IVA task time.

Engineering Prototype Development

Program Content Guided by a Series of Focused Studies:

- Advanced Development Task Force (LaRC/Hook), 2/88
- SSF Advanced Automation Study, 5/88
- FTS Evolution Plan, 10/89
- SSFP Automation Review & Testbed Study, 12/89
- Astronaut Productivity Study, 3/90
- NASA Computational Requirements Workshop, 7/90
- External Maintenance Task and Solutions Team, 7/90
- NASA Telerobotics Testbed Study, 10/90
- DMS Baseline Assessment & Evolution Study, 1/91

Engineering Prototype Development

Restructuring Issues Emphasizing Automation and Robotics

Even prior to restructuring it was widely recognized by the Space Station community that operations would be constrained by the availability of crew and system resources. With the restructuring of Space Station Freedom even more emphasis must be placed on utilizing the available resources in an efficient manner. With a minimal Manned Tended Configuration and Permanently Manned Configuration (PMC) resources such as Power, Crew, DMS, C&T, etc must be utilized efficiently. With the several years of Manned Tended operation, the systems will be manned on-orbit for only small fraction of the time. As a result it is important to assure high productivity during Shuttle visits and utilize Station as much as possible during unmanned periods via remote monitoring, control, and reconfiguration of systems.

In addition, long term operation in the PMC time period with manually intensive systems might require more than the two housekeeping Crew for IVA and EVA activity. Assuring sufficient Crew for payload operations will be accomplished through emphasis on reducing system IVA tasks and task time.

NASA OSF

Engineering Prototype Development

FREEDOM

Restructuring Issues Emphasizing Automation and Robotics:

- **Minimal MTC, PMC configurations have reduced resources & redundancy -- Power, Crew, DMS, C&T, Racks**
- **Longer time between MTC and PMC configurations**
  - **High productivity during Shuttle visits important**
  - **Utilization during unmanned periods important**
  - **Remote monitoring, control, and reconfiguration of systems during unmanned periods critical**
- **PMC configuration Crew/systems reduction impacts operations and utilization**
  - **Manually intensive systems might require >2 housekeeping Crew (IVA and EVA)**
  - **Reduction of crew dedicated to payload operations at PMC**

Engineering Prototype Development

Objectives

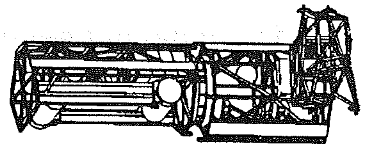
The objective of Engineering Prototype Development is to independently evaluate current baseline system function and performance and develop prototypes to enhance baseline SSF flight and ground systems capabilities. Task objectives include improving productivity and reliability of selected subsystems by applying appropriate technologies; reducing EVA and IVA task time to reduce Crew workload and provide time for high priority applications; Reducing technological obsolescence by identifying system problem areas, and growth options; and identifying options for reducing power consumption and weight.

In addition to the baseline focus indicated above, a secondary aspect of Engineering Prototype Development is to provide enabling technology for SSF evolution by developing prototypes for advanced automation and robotic applications for EVA Systems, ECLSS, and DMS.

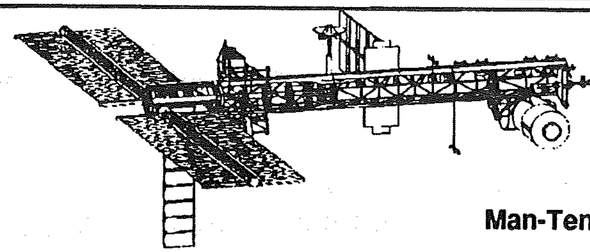
NASA
OSF

Engineering Prototype Development

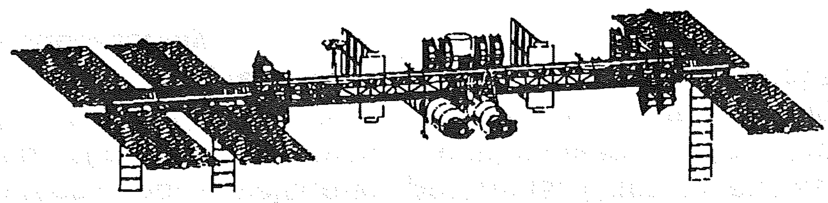
FREEDOM



First Element Launch



Man-Tended Configuration



PMC and Beyond

OBJECTIVES:

- **Enhance baseline SSF flight and ground systems capabilities**
  - **Improve productivity & reliability**
  - **Prevent technological obsolescence**
  - **Reduce EVA, IVA task time**
  - **Reduce power consumption and weight**
- **Provide enabling technology for SSF evolution**
  - **Advanced EVAS, ECLSS, DMS, automation & robotics applications**

SSFevolution/8-7-91

Engineering Prototype Development

Approach

The approach for Engineering Prototype Development is to evaluate technologies for selected flight and ground systems via focused studies and subsystem evaluations. An important aspect in deciding on focus for the work is developing programmatic relationships with other NASA offices and Government agency research and technology development programs. Often the expertise for understanding the approach or application of an advanced system requires teaming of technologists and operations or user organizations. Building such teams is an important aspect in assuring effective technology transfer. As has been often stated, technology transfer is a "body contact sport" requiring close working relationships to do it successfully.

Each application or prototype is unique in the mix of conventional and advanced techniques. It is incumbent on the task team to decide on the appropriate mix of these techniques in developing a prototype that realistically takes the Space Station resource and operational environment into consideration. As such, transition and implementation issues are addressed early.

Developing and testing technology in a laboratory is only the first step in developing successful prototypes and evaluating systems. Demonstrating the prototypes on high fidelity testbeds and performing operational evaluations with technologist , engineering and operations personnel involved is imperative in evaluating the success or progress of a prototype development. Included in the approach is documenting performance requirements and design accommodations for technology insertion and implementation in the SSF baseline systems.

NASA

OSF

Engineering Prototype Development

FREEDOM

APPROACH:

- Evaluate technologies required to achieve objectives for SSF and ground systems
- Leverage NASA and other Government agency research and advanced technology development programs
  - OAET, NSTS, OSSA
  - DARPA, USAF, Navy, SDIO
- Build user/technologist teams within, and between, flight and research centers
- Develop applications using mix of conventional & advanced techniques
- Address transition and implementation issues early
- Demonstrate applications using high fidelity testbeds and "operational" evaluations
- Document performance requirements, design accommodations for technology insertion and implementation

Engineering Prototype Development

Products and Benefits

As a result Engineering Prototype and Development tasks provide high fidelity demonstrations and evaluation of candidate applications using advanced technology where appropriate. The SSF program is provided with an understanding of requirements, performance specifications and design accommodations required for improving the functionality or performance of monitoring and diagnostics or operations of a system. In addition, a level of maturity in technology, tools and applications can be demonstrated for SSF flight and ground systems so that informed decisions can be made in the application of technology on the Program.

Engineering Prototype Development

PRODUCTS & BENEFITS:

- "Engineering" fidelity demonstrations and evaluations of advanced technology
- Detailed requirements, performance specifications, and design accommodations for insertion of advanced technology
- Mature technology, tools, and applications for SSF flight and ground systems
- Increased confidence in, and reduced risks associated with, new technologies

Engineering Prototype Development

Tasks evaluated for their potential to

As with any activity of this nature, there is always more work to do than resources to apply. In addition, it is necessary on a periodic basis to evaluate or prioritize new projects which are candidate additions. We have developed a set of criteria, along with a process for evaluating and prioritizing the work in Engineering Prototype Development. The process involves weighted criteria and subjective elements.

NASA
OSF

Engineering Prototype Development

FREEDOM

Tasks evaluated for their potential to:

- **Address Baseline and Restructuring Issues**
- **Impact program phases (FEL, MTC, PMC)**
- **Improve baseline system/subsystem functionality**
- **Reduce baseline development costs and risk**
- **Reduce operational costs**
- **Reduce life-cycle costs**
- **Increase scientific return**
- **Enhance safety**

NASA OSF

Engineering Prototype Development

FREEDOM

WBS Structure

The four areas of Engineering Prototype Development include:

Flight and Ground Systems which is focused on providing prototype monitoring and diagnostic systems.

SSF Data Systems which focuses on characterizing baseline DMS performance, growth options, and evaluation of candidate DMS user interfaces.

Advanced Software Engineering which is developing tools methodologies to support the design, development and maintenance of advanced software applications.

Telerobotic Systems which is focused on providing hardware and software technologies to improve operator-telerobot interfaces and to enhance telerobotic control.

Engineering Prototype Development

WBS STRUCTURE:

- **Flight and Ground Systems**
- **SSF Data Systems**
- **Advanced Software Engineering**
- **Telerobotic Systems**

Engineering Prototype Development

Flight and Ground Systems

Advanced automation applications are being developed to make SSF flight and ground systems more reliable. The approach relies heavily on Fault Detection, Isolation and Recovery (FDIR) methods and provides a range of support in system-status monitoring, safeing and reconfiguration. A mix of conventional and Knowledge-Based System (KBS) techniques is used and each application provides a powerful user interface to support advisory mode interactions. The primary benefits are increased systems reliability through improved systems monitoring, enhanced fault detection and isolation capabilities, and increased productivity for Mission Control Center (MCC) personnel and SSF crew members.

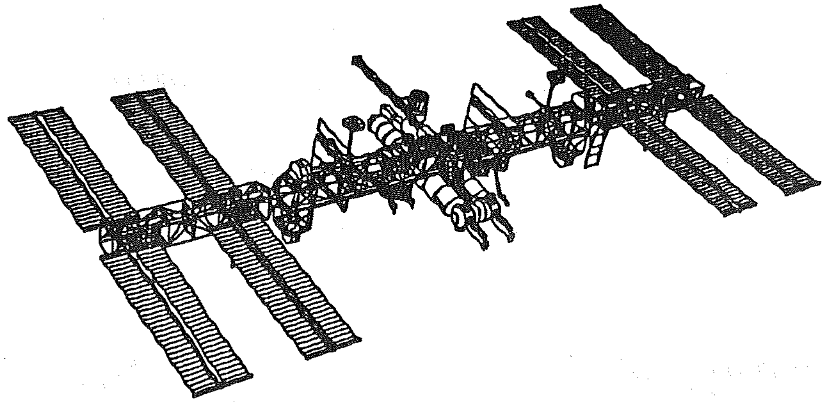
Application prototypes are being developed for selected SSF distributed systems and control centers. Intelligent FDIR advisory systems already have been developed and demonstrated in support of Shuttle flight operations.

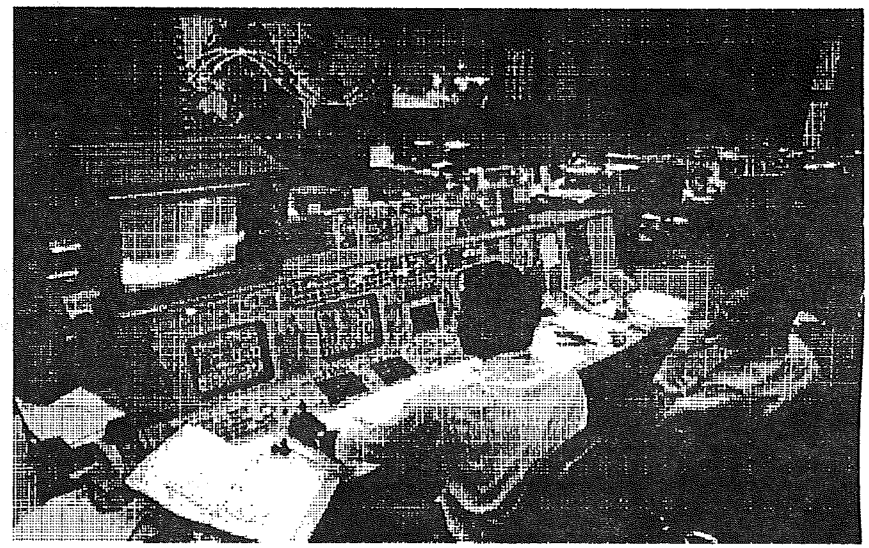
Engineering Prototype Development

NASA OSF

Flight & Ground Systems Automation
WBS Element Summary

FREEDOM





ORIGINAL PAGE IS
OF POOR QUALITY

273

OBJECTIVES:

- **Provide mature technology for distributed monitoring & FDIR**
- **Identify and document design accommodations**
  - **Instrumentation, redundancy management**
  - **Interfaces with DMS,C&T,conventional SSCC and POIC s/w & h/w**
  - **Software development and verification**
- **Demonstrate FDIR and data monitoring for payloads**
  - **Troubleshoot Rapidly**
  - **Improve timeline utilization**
  - **Manage available experiment resources**

Engineering Prototype Development

Flight & Ground Systems Automation
WBS Element Summary

APPROACH:

- Combine conventional monitoring and FDIR procedures with knowledge-based approaches to develop "intelligent" advisors for mission operations
- Develop FDIR application prototypes for selected SSF systems, the SSCC, and Engineering Support Centers
- Develop and validate software using established MCC policy and procedures. Use a mix of DMS/SSE tools and demonstrate on DMS-equivalent hardware
- Demo to SSF Work Package and contractor mngt and engineers on high fidelity program testbeds and in "operational" evaluations
- Coordinate transition of documented requirements, applications, and s/w development tools to Work Packages, MCC, SSC, etc
- Joint Funding with SSP, OAET, OSSA, DARPA

Engineering Prototype Development

Flight & Ground Systems Automation
WBS Element Summary

PRODUCTS & BENEFITS:

- **Detailed system requirements, performance specifications, & design accommodations**
- **"Intelligent" FDIR advisory systems have been developed and demonstrated in the MCC**
  - **INCO, SSME, RMS, EGIL, GN&C, Flt Dir Wind Advisor**
  - **Used operationally since STS-26**
- **FDIR applications under development for Power Management and Control/Distribution; Thermal Control; Environmental Control and Life Support; & SLS-2 Life Sciences Payload**
- **Improved fault isolation, detection of incipient failures, increased system reliability with a reduced mean time to repair; reduced instrumentation, reduced EVA/IVA maintenance, reduced backroom workforce, reduced life-cycle costs**

Engineering Prototype Development

Flight & Ground Systems Automation WBS Element Summary

FY91 Tasks:

- **Thermal Control Automation, JSC**
- **ECLSS Automation, MSFC**
- **ECLSS Predictive Monitoring, JPL**
- **Power Management & Distribution Automation, MSFC**
- **Power Management & Control Automation, LeRC**
- **Astronaut Scientific Associate, ARC**
- **Real Time Data Systems, JSC**

Engineering Prototype Development

Data Systems

The computer and network architectures of the SSF Data Management System (DMS) are being analyzed to provide increased performance and reliability and to determine long-range growth requirements. Additionally, advanced mission planning and scheduling tools are being developed and demonstrated for use onboard, as well as on the ground.

Advanced DMS architectures are being evaluated with respect to : existing and proposed uni- and multiprocessors; network, protocol and connectivity options; and system management software. In addition, DMS interface options and computer hardware and software interfaces are being evaluated on Shuttle flights to resolve user interface problems.

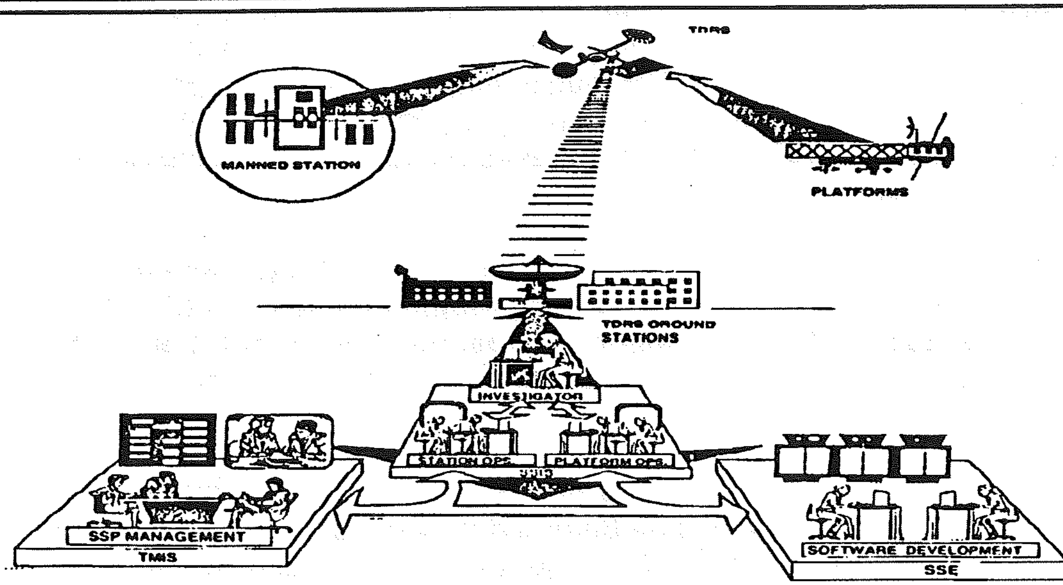
The development of planning and scheduling systems using Ada-based KBS software tools should result in improved productivity and reduced software lifecycle costs. The Computer-aided Planning and Scheduling System (COMPASS) interactive scheduling tool, which includes optimization techniques is being used to judge the validity of short-term plan event execution. There is significant potential for using COMPASS on a variety of ground- and flight-based resource and event scheduling applications.

NASA
OSF

Engineering Prototype Development

Space Station Data Systems
WBS Element Summary

FREEDOM



OBJECTIVES:

- **Increase Space Station DMS performance and reliability**
  - **Reduced power & weight, increase throughput and storage**
- **Demonstrate advanced processors, storage devices, displays, and network components; document long-range growth requirements**
- **Develop and demonstrate advanced ground-based and on-board mission planning and scheduling tools for the ISE, SSCC, & POIC**

SSFevolution/8-7-91

Engineering Prototype Development

Space Station Data Systems
WBS Element Summary

APPROACH:

- **Analyze baseline DMS using a mix of hardware and dynamic simulations**
- **Evaluate DMS component upgrades incrementally to determine performance/power benefits and compatibility with baseline DMS architecture**
- **Develop and demonstrate KBS planning and scheduling tool using Ada language and ISE/DMS software and hardware constraints**

Engineering Prototype Development

Space Station Data Systems WBS Element Summary

PRODUCTS/BENEFITS:

- **Enable growth of DMS and OMA infrastructure and prevent technological obsolescence**
  - **Extensible hardware, software architectures**
  - **Improved performance in processors, mass storage, data networks**
  - **Reduced power and weight; increased reliability**
- **Reduced cost for software development, testing, and maintenance of mission planning and scheduling systems**

NASA
OSF

Engineering Prototype Development

Space Station Data Systems
WBS Element Summary

FREEDOM

<u>*FY91 Tasks:*</u>

- **Advanced DMS Architectures, ARC**
- **Optical Protocols for Advanced Networks, JPL**
- **Advanced Portable Crew Support Computer, JSC**
- **ISE Advanced Scheduling System, JSC**
- **KBS Scheduler Re-host, JPL**

NASA OSF

Engineering Prototype Development

FREEDOM

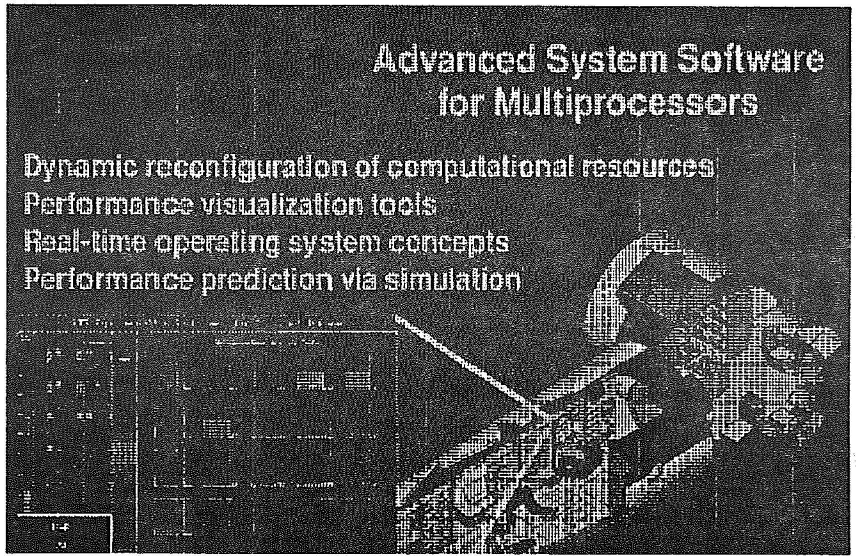
Advanced Software Engineering

Space Station Freedom will require a significant amount of application and support software. Development of software tools, methodologies, and environments is being pursued to support the design development, and maintenance of advanced software applications. Tasks have included investigating Ada cross-compilers for existing KBS tools and benchmarking their performance using operational automation prototypes. Also, Computer-Aided Software Engineering (CASE) tool sets supporting the reuse of design information are being developed. In addition, tools and techniques for software verification, validation, testing, and maintenance are being developed and demonstrated.

Because of SSF complexity, the demand for training operations staff and crew is even greater than that for Shuttle missions. The extension of Shuttle training methods to SSF may prove impractical. Using artificial intelligence technology provides the ability to simulate individualized training to many personnel in a distributed workstation environment. Intelligent Computer-Aided Training (ICAT) architectures are being developed and demonstrated in operational settings. ICAT technology offers training improvements by reducing the overhead involved in setting up training environments, scheduling classes, and developing simulations.

Engineering Prototype Development

Advanced Software Engineering
WBS Element Summary



***OBJECTIVES*:**

- **Develop and demonstrate programming tools that reduce software development and maintenance overhead**
- **Provide software development tools for knowledge-based system (KBS) applications for integration with the SSE**
  - **KBS tools (rule-, frame-, and model-based) that produce Ada code**
  - **KBS verification and validation techniques**

Engineering Prototype Development

Advanced Software Engineering WBS Element Summary

APPROACH:

- **Develop & demonstrate Ada cross-compilers for commercial KBS tools**
- **Benchmark their performance using flight systems automation prototypes (e.g., ECLSS, PMAC, PMAD)**
- **Develop and demonstrate verification, validation, testing, and maintenance tools and techniques for conventional and KBS software**
- **Coordinate closely with SSE personnel (JSC, Lockheed, PRC)**

Engineering Prototype Development

Advanced Software Engineering WBS Element Summary

PRODUCTS & BENEFITS:

- **Established DMS performance and memory requirements for KBS software in Ada**
- **Demonstrated ability to develop, deploy, test, and maintain KBS software compliant with SSE language and methodology & DMS requirements**
- **Reduce cost, time for development, and maintenance of conventional & KBS flight and ground system software**

Advanced Software Engineering WBS Element Summary

FY91 Tasks:

- **Software Life Cycle Methodologies & Environments, JSC**
- **SSF Software Reconfiguration, JSC**
- **Failure Environment Analysis Tool, JSC**

Engineering Prototype Development

Telerobotic Systems

Key hardware and software technologies are being advanced to improve operator-telerobot interfaces and to enhance telerobotic control. These technologies will allow telerobots to do more work in less time, with greater safety and reliability. The increased use of telerobotics reduces the need for EVA, while enhanced control reduces the IVA time required to perform telerobotic tasks.

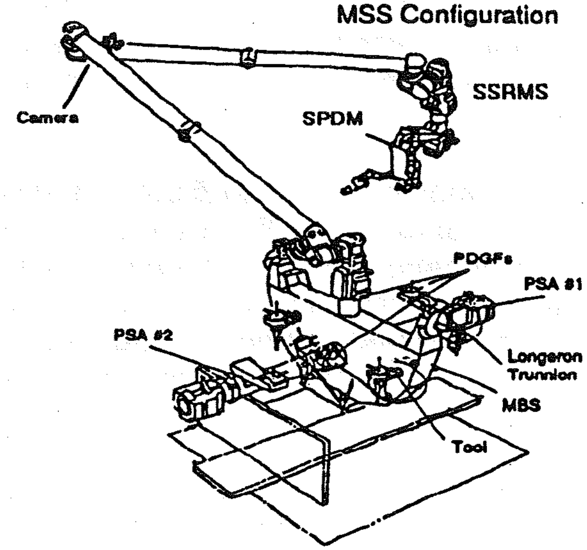
The development of a "shared control" capability will provide a robust operator interface and better management of control loop time delays. A human operator may select the level of autonomous control desired to move the robot faster and accomplish tasks with fewer commands and less stress. Development of a standardized, segmented control architecture compensates for telecommunication or computation-induced time delays, improving teleoperation by IVA crew and allowing remote operation of the Station's telerobots from ground-based consoles.

Proximity sensors have been developed to improve telerobotic collision detection and avoidance. A break-through technology has created reflecting capacitor sensor arrays that may be mounted on the outside of the telerobot, much like an extended skin. Sensors and associated logic, integrated into a flexible applique' covering, can direct the telerobot to stop, back away from, or work around any object within 12 inches of the robot. This results in greatly simplified dynamic model-based approaches, and ultimately, less time needed for the telerobot to complete a task.

Engineering Prototype Development

Telerobotic Systems
WBS Element Summary

MSS Configuration



OBJECTIVE:

- **Improve operations capability through more effective use of baseline SSF systems**
  - **Reduce required manned EVA operations time**
  - **Enhance EVR teleoperations safety & reliability margins**
  - **Reduce IVA teleoperations time at MTC and beyond**

Engineering Prototype Development

Telerobotic Systems
WBS Element Summary

APPROACH:

- Utilize existing NASA robotic testbeds (JSC, JPL, GSFC) to integrate and demonstrate advanced robot control, task and spatial planning, and collision avoidance algorithms
- Transition advanced algorithms to Ada and demonstrate on dexterous tasks
  - Collect performance data, determine DMS requirements
  - Determine integration path into SSF subsystems
- Assemble mockups and perform maintenance/inspections using mix of teleoperation and autonomy
- Develop collision avoidance sensor arrays and demonstrate on laboratory robots
  - Investigate control strategies and integration with model-based collision avoidance

C-4

Engineering Prototype Development

Telerobotic Systems
WBS Element Summary

PRODUCTS & BENEFITS:

- **Improved robotic capabilities to reduce EVA time required for inspection, assembly, and maintenance**
- **Improved interface and shared control to increase safety of teleoperation and reduce IVA time required for robotic operations**
- **Increased telerobot resource utilization through multiplication of operators effecting ground remote operation of SSF telerobots**
- **Semi-autonomous assembly of SSF structures will reduce long-term EVA requirements**

NASA
OSF

Engineering Prototype Development

Telerobotic Systems
WBS Element Summary

FREEDOM

FY 91 Tasks:

- **Flat Target (JPL)**
- **Automated Robotic Maintenance of SSF (JSC)**
- **Advanced Telerobotic Control and Interfaces (JPL)**
  - **User Macro Interface & Shared Control**
  - **Operator Coached Machine Vision**
- **Collision Avoidance Sensor (GSFC)**

Engineering Prototype Development

Summary

- **Engineering Prototype Development is the Space Station Freedom effort to enhance flight and ground system capabilities by prototyping applications of advanced technology**

- **The FY91 restructuring of Advanced Development has been completed successfully**

- **Solid task mix in place that addresses critical baseline program issues (e.g., reduced instrumentation, minimal DMS/ISE, oversubscribed EVA and IVA)**

- **Task demonstrations are aligned with critical program milestones**

Space Station Freedom Program Commercial Infrastructure and Technology Utilization

Kevin Barquinero
Space Station Engineering Division
Office of Space Flight

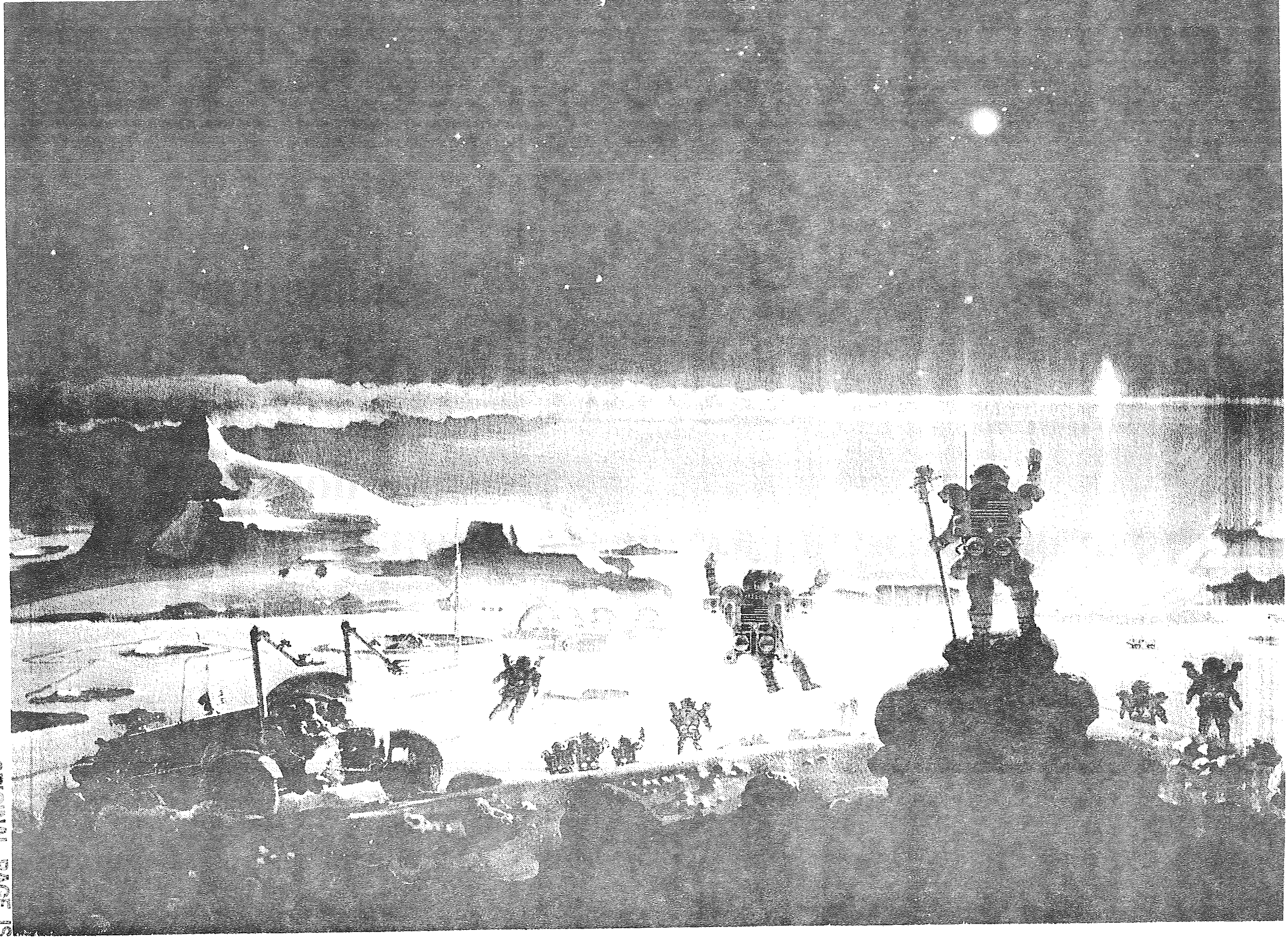
Topics

- Commercial Infrastructure Participation in SSF Evolution

- Commercial Utilization of SSF–developed Technologies

PRECEDING PAGE BLANK NOT FILMED

294 INTENTIONALLY BLANK



Importance of Commercial Space Infrastructure

- Government cannot be expected to make total investment
- Commercial participation is essential
- Industry has thirty years of space experience
- Requirement:
  - -- Risks are quantifiable
  - -- Expected return commensurate with risks

Importance of Space Station Freedom

- Will reduce the risk of commercial space activity
  - -- Technical
  - -- Market
  - -- Financial

- Creates opportunity for commercial ownership and operations of discrete space systems and services
  - -- Power Services
  - -- Data Services
  - -- Communications Services
  - -- Ground Services
  - -- Transportation Services
  - -- User Services

Benefits

To Industry:

- Entry into an emerging market
- Long term profits and return on investment
- Access to new technologies
- Market expansion

To NASA:

- Reduced up–front expenditures
- Investment into new R&D
- Expanded participation and support for SSFP
- Support for National Space Policy

Challenge to Advanced Studies Program

- Recognize potential role of commercial infrastructure
  - -- Policy
    - – Private capital at risk
    - – Non-U.S. government customers
    - – Commercial market determines viability
    - – Private sector has responsibility and management of activities

- Identify potential opportunities for commercial infrastructure
  - -- Criteria
    - – NASA Space Commerce Opportunities planes nine initiates

Topics

- Commercial Infrastructure Participation in SSF Evolution

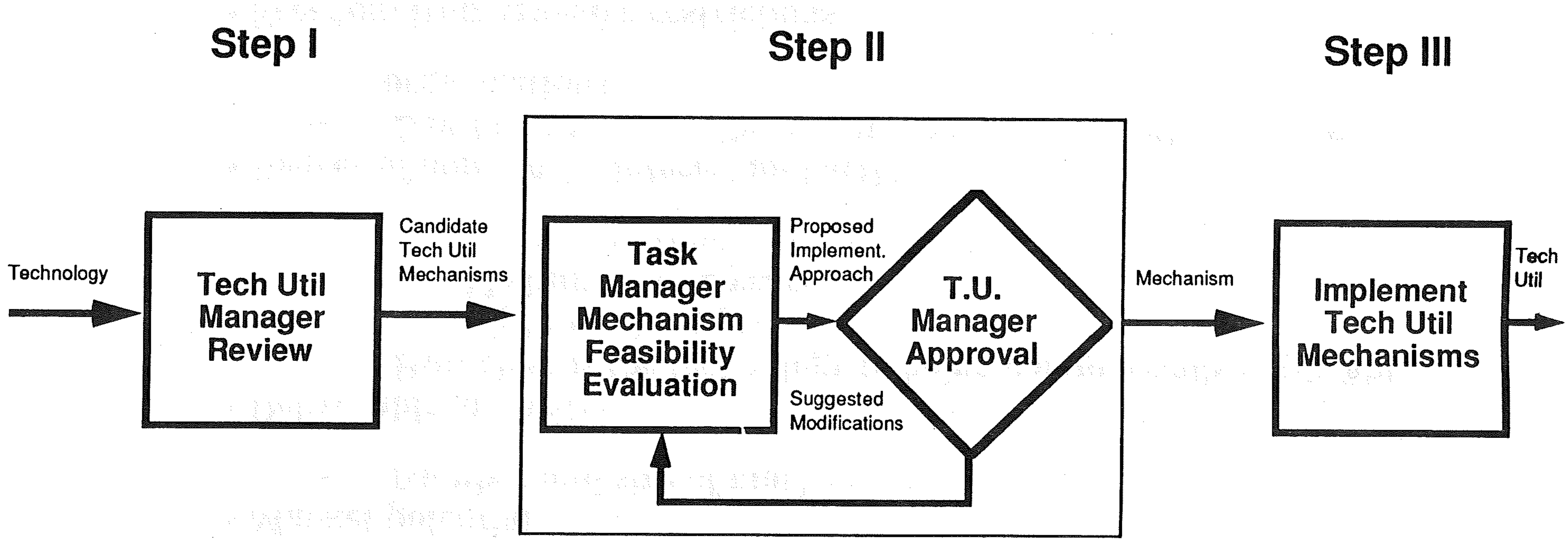
- Commercial Utilization of SSF–developed Technologies

Technology Utilization Goals

- Facilitate U.S. industry's utilization of technologies developed within the Space Station Freedom Program

- Establish a standard approach to identify opportunities for commercial utilization of SSF technologies

Technology Utilization Process



Note: Current scope focuses on the Engineering Prototype Development and Evaluation Program. Process can be adapted to cover additional station and other NASA technologies.

KB-8
7/23/91

Technology Utilization Criteria

POTENTIAL COMMERCIAL UTILITY EVALUATION CRITERIA

- Market potential
  - -- Number and size of markets
- Deliverable maturity
  - -- How close is the technology to being commercially applicable
    - High: working prototype
    - Medium: 1 to 2 years
    - Low: more than 2 years
- Degree of non-NASA interest and activity
  - -- Level of interest in the private sector and in other government organizations
- Freedom from transfer restrictions
  - -- Is the technology free from restrictions on its transfer to the private sector
    - High indicates no transfer restrictions
    - Zero indicates complete restriction from transfer

Technology Utilization Mechanism

- Active mechanisms include:
  - -- Joint Sponsored Research Program
  - -- Federal Technology Transfer Act Cooperative Research and Development Agreement
- Passive mechanisms include:
  - -- Publication In Tech Briefs
  - -- Conferences and Seminars
  - -- Industrial Application Centers
  - -- Computer Software Management and Information Center (COSMIC) Database

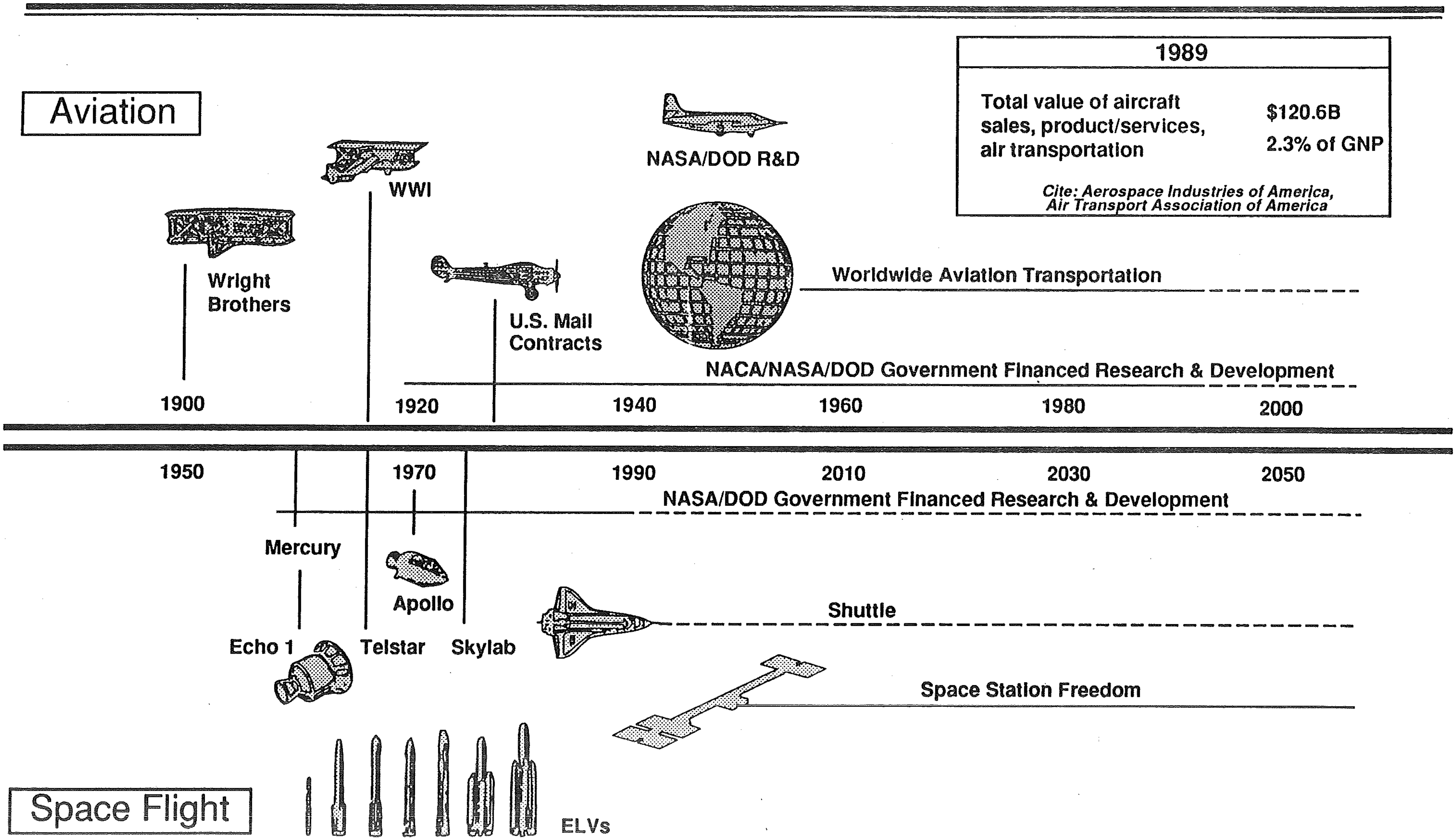
KB-10
7/23/91

Challenge to Engineering Prototype Development Program

- Recognize potential commercial value of technology
  - -- Personal knowledge
  - -- Criteria
- Support efforts to employ technology utilization mechanism

KB-11
7/23/91

Comparison of Aviation and Space Development



KB-12
7/23/91

NASA FREEDOM

Evolution Design Requirements and Design Strategy

Space Station Evolution Beyond the Baseline – 1991

August 7, 1991

Donald W. Moneil
NASA – LaRC
SSFO / APO

Overview

Drivers for Growth / Evolution

Evolution of Space Station Freedom is justified for reasons which vary from more effectively utilizing the manned base to providing a means for incorporating new technologies as they come become available. Increasing or, more importantly, balancing the resources that are provided to the users is very critical to effectively utilizing the station. At permanently manned phase of the program, there will be four crew members that will be supporting and monitoring three laboratories. Accepted user mission databases have shown a demand for more crew, power, and volume than is provided by the baseline. As the work done in space by NASA continues to expand, the station will take a more active role in the missions. New functionalities for its operation and support of other missions will be required. One important driver for growth, particularly in the area of structures, is the inability of the baseline configuration to store all the ORU spares that will be required on–orbit. New technologies drive growth by providing a means of streamlining operations and possibly reducing the demand on EVA. They will also ensure that the station does not become plagued with obsolete equipment.

Drivers for Growth / Evolution

- **Increase resources for users**
  - Reduce time–sharing of critical resources at PMC (particularly power and crew)
  - Increase utilization by expanding user volume (LAB B)
  - Provide balanced resources for expanded user volume
- **Provide new functionality for users and station operations**
  - New classes of user payloads (e.g., large external payloads)
  - New functionality within station–provided services
    - GN&C and procedures for ELV–delivered cargo
    - Free–flyer servicing
- **Incorporate new technologies**
  - Reduce operations costs and increase utilization
  - Decrease EVA requirements
  - Avoid obsolescence

Design for Growth

If growth is not considered during the initial design process, implementing the follow–on and evolution phase plans could prove to be very complicated. More specifically, it could be either too costly or operational complex. Follow–on and evolution phase configuration design features that fall into these two categories need to be "flushed–out" promptly. Scars for all element and system growth need to be identified as soon as possible such that the impact to the baseline design is minimized. The farther along the design is, the more difficult changes will be. As will be shown in the following pages, there are certain scars that need to be installed on the baseline to permit growth beyond PMC.

Design for Growth

- **Potential impacts of not considering growth in the baseline design process include:**
  - Prohibitive costs for growth retrofit
  - Increased operational complexity for on–orbit upgrades
- **Impact of accommodating future growth in baseline design will be minimized if acted upon now**
  - Many "scars" have minimal cost and weight
  - Restructuring detailed design is in progress
  - As CDR approaches, requirements changes will carry significant costs
- **Although SSF is designed to provide phased capability, design features in the first configuration (MTC) are required to enable growth to the follow–on and evolution phases**

Follow–on Phase "Design–to" Strategy

The Space Station Freedom follow–on phase has been addressed in several forms throughout the program. A commitment to achieving 75 kW power generation capability and 8 crew capability, at some point in the program, is contained within the international MOUs. The Integrated Systems Preliminary Design Review, the SSF Restructuring Directive and the WP–02 White Papers all provide information concerning systems and elements that will most likely be included during this phase of the Space Station. Those items required to fulfill the international MOUs commitments will have to be placed in orbit during the buildup to this phase.

The precise configuration for this phase is currently being identified and analyzed in the Space Station Freedom Office at the Langley Research Center. As a result of the program having some understanding of what the follow–on phase entails, the scarring approach should minimize hardware replacement and retrofit, ensuring a smooth transition from the Permanently Manned Configuration.

Follow–on Phase "Design–to" Strategy

- ISPDR and SSF restructuring directive (BB000986R1) provide basis for follow–on phase
- Follow–on phase elements represent high probability, early growth additions; particularly those items required to fulfill the international MOUs (75 kW and 8 crew)

Baseline scarring approach should minimize hardware replacement and retrofit for the follow–on phase

Evolution Phase "Design–to" Strategy

The design strategy for accommodating the evolution phase of Space Station Freedom is one that supports some degree of flexibility within the design. This requires that growth be considered in, but not drive, the initial design of the station. This also requires that critical scars be identified and incorporated in the initial design such that show–stoppers to general growth flexibility are avoided. At the Permanently Manned Configuration phase of the program, there should remain within the design some option as to which evolution path will be pursued. The method of scarring for the evolution phase, however, shall be one that minimizes the impact to the baseline design.

Evolution Phase "Design–to" Strategy

- **Flexibility rather than rigid point–design**
  - Multiple options for evolution paths
  - Generic design features
- **"Design–for–growth" focusing on minimal impact approach**
  - Consider growth in initial design
  - Incorporate a few critical scars to avoid *show–stoppers* to general growth flexibility
  - Do not use life–cycle cost as a justification

Scarring approach for the evolution phase should minimize impact to the baseline design (weight, power, and cost)

Evolution Requirements Background

Evolution requirements have impacted the design of Space Station Freedom to varying degrees during the past seven years. The Program Requirements Document (PRD) has always included a set of evolution requirements. This set has been kept current by continually updating the requirements based upon the results from the element and distributed systems studies funded through the Advanced Studies Program. The Program Definition and Requirements Document (PDRD) included a set of evolution requirements until the 1989 program rephasing.

The *disconnect* between the PRD evolution requirements and the PDRD was brought to light during the ISPDR. All Review Item Discrepancies (RIDs) concerning evolution were assigned to the traceability team and disapproved with an action to resolve the PRD/PDRD disconnects via deletion or modification of the existing requirement.

Level I Advanced Programs Office and the Langley Research Center SSFO worked through the action, and a preliminary Level I / Level II meeting to discuss evolution requirements was held January 31, 1991 at Reston. The results of the evolution requirements work performed by Level I and LaRC were then presented to the Director for SSF on March 1. A PRD CR with follow–on and evolution phase requirements was signed out–of–board by the Director for SSF on June 14, thus baselining a limited set of critical requirements in Rev D of the PRD. The Level II Manager of Distributed Systems was briefed on the evolution requirements and the ongoing studies that support the requirements on June 14. Subsequently, a draft PDRD CR that "flows down" the evolution requirements from the PRD has been developed by Level I and Level II.

Evolution Requirements Background

- **Evolution requirements originally were included in the SSF Program**
  - Scrubbed from PDRD during 1989 rephasing
  - Retained in PRD and updated based on results of Advanced Studies Program
- **Lack of flow–down of evolution requirements from PRD to PDRD was recognized during ISPDR**
- **A reduced set of critical evolution requirements was baselined in the PRD Rev D**
- **A draft PDRD CR that flows down evolution requirements from the PRD has been developed between Level I and Level II**

Requirements, Approaches, and Baseline Impacts

Critical Evolution Requirements

Since the ISPDR, the evolution requirements contained within the PRD have been reduced from 45 to six. The six *critical* requirements are as follows: 1) the ability to increase the total power generation and distribution capability of the station, and the ability to distribute growth power to the baseline elements; 2) the ability to increase the Thermal Control System heat rejection capacity commensurate with power growth; 3) the ability to increase data processing, transfer, and storage capability of the Data Management System; 4) the ability of the station to accommodate an advanced Extravehicular Mobility Unit; 5) the ability to augment the transverse boom with growth structure; and, 6) the ability to add pressurized volume. When considered during the initial design process, these six requirements will provide a basic flexibility for Space Station Freedom to evolve, independent of the specific evolution path (e.g., SEI, expanded R&D, etc.).

Critical Evolution Requirements

- **Ability to add power**
  - Total power generation and distribution capability
  - Power distribution to baseline elements (modules)
- **Ability to increase thermal rejection capacity commensurate with power growth**
- **Ability to increase data processing, transfer, and storage capability**
- **Accommodation of an advanced EMU**
- **Ability to add structure**
- **Ability to add pressurized volume**

These six requirements are needed to provide basic flexibility for Space Station Freedom evolution independent of the specific evolution path

“Design–for–Growth” Strategy

The requirements presented here identify the method of scarring that will be pursued for both the follow–on and evolution phases. Scarring for the follow–on phase shall be “installed up–front” in the baseline configuration. The elements and distributed systems which are slated to be part of the follow–on phase are summarized in Table 3.3–2 of the PRD. The scarring approach for the evolution phase is identified as one that “minimizes the impact on the baseline design in the areas of weight, power, and development cost.” Identification of growth elements and distributed system upgrades that will be included in the evolution phase configuration of Space Station Freedom is currently underway at the Langley Research Center SSFO.

"Design–for–Growth" Strategy

PRD Rev D Requirement(s)

- **Program Summary PRD 1.3**
  - ...All systems shall be scarred to accommodate all the Follow–on Phase requirements specified in this document
  - ...The approach to meeting requirements for the Evolution Phase shall be one that minimizes the impact on the baseline design in the areas of weight, power, and development cost.

Electrical Power System Growth

The requirement for power generation states that the station shall allow for evolution to a capability of 150 kW orbital average power. This growth power level resulted from multiple utilization analysis iterations using varying allocation assumptions. The requirement that the Power Management and Distribution (PMAD) design shall allow for the distribution of *growth* power (power generated by additional power modules brought to orbit during the buildup to·the evolution phase) to the baseline loads will be added by directive to the PRD. This requirement was inadvertently dropped from the CR during the final editing process.

Replication or retrofit of the baseline EPS hardware (i.e., MBSUs, power modules, SPDAs, etc.) constitutes the minimum impact approach of achieving the growth power generation and distribution requirement. Installation of the associated growth electrical utility lines can be deferred until they are needed for distributing growth power. Deferral of these two aspects of the EPS growth is necessary because of the weight associated with the equipment and the current state of the baseline weight allocations.

The Solar Alpha Rotary Joint provides the following three functions: 1) sun tracking rotational movement of the PV arrays; 2) structural load transfer between the inboard and outboard truss members, and; 3) transfer of 160 VDC power and 1553B data across the Alpha Joint. Increased load transfer capability could be attained by replacement or retrofit of the SARJ trundle bearing packages, and, subsequently, the drive motors and Rotary Joint Motor Controllers (RJMCs). The impact on non–ORU components of this method of structural upgrade is currently being investigated. Power and data are transferred across the alpha joint by means of the Utility Transfer Assembly (UTA), which is an ORU. The baseline UTA design contains 18 power "roll rings" (4, 4 wire channels) and 24 data "roll rings". The minimum impact approach to power and data transfer upgrades would entail changeout of the baseline UTA with the UTA designed previous to Restructuring (24 power roll rings and 48 data roll rings). A study is underway which addresses the details of the evolution requirements for the SARJ and the means of satisfying them.

Electrical Power System Growth

- **PRD Rev D Requirement**
  - 3.4.5.4.4 The Electrical Power System (EPS) shall allow for growth to provide up to 150 kW orbital average power (Table 3.3–3)

To be added by Directive to PRD:

  - 3.3.2.3.5 The Power Management and Distribution (PMAD) design shall allow for growth to accommodate the distribution of power during the Evolution Phase to the baseline loads

- **Minimum Impact Approach**
  - Replicate or retrofit EPS hardware for growth
  - Defer growth electrical utility lines
  - Upgrade SARJ utility transfer assembly (UTA)
  - Replace or retrofit SARJ trundle packages, drive motors, and Rotary Joint Motor Controllers (RJMCs)

Electrical Power System Growth (Cont.)

A "growth" inertia requirement is being levied upon the design of the drive system. Analysis is underway to determine whether the equipment to be located outboard of the alpha joints during the evolution phase of the station has inertia properties that exceed the capability of the motors. The rotation capability can be upgraded by replacing the drive motors and RJMCs, as was presented on the previous chart. However, the design–limiting factor of this upgrade is the load carrying capability of the race bull gear, which, as an integral part of the bearing assembly structure, is not an orbital replaceable unit (ORU). Similarly, replacing or adding trundle packages on–orbit will allow for greater load transfer, but could also cause the race ring and "skirt" (non–ORU) to buckle.

There are several potential impacts to the baseline that result from these minimum impact solutions, although the degree of impact varies. One impact that is common across all distributed systems is reserving volume/access for growth hardware. A prime example of this impact is the identification of volume required for additional or upgraded MBSUs (required because there is a minimal number of spare RBIs within the baseline configuration). Placement of the electrical utility lines associated with the growth of the EPS will need to be identified. As a result of being a non–ORU, the SARJ bearing assembly, which consists of the skirt, race ring, ribs, T–rings, and hubs, will need to be sized for growth loads.

Electrical Power System Growth (Continued)

- **Installed Capability**
  - Structural capability of non–ORU SARJ components (skirt, race ring, ribs, T–rings, and hubs) must be adequate for growth
- **Potential Baseline Impacts**
  - Reserve volume/access for growth hardware (e.g., MBSUs)
  - Room for the addition of growth electrical lines
  - SARJ bearing assembly designed for growth loads

Thermal Control System Growth

The intent of the growth Thermal Control System (TCS) requirement is to ensure that the design of the system allows for upgrading the heat rejection capability consistent with the increased heat loads generated by the power system, crew, and equipment during the evolution phase. An initial assessment of the endpoint heat rejection capability during the evolution phase results in a growth load of ≈ 165 kW.

Placement of "growth" radiators on the station has been severely constrained as a result of the the Pre–Integrated Truss (PIT) design which came out of restructuring. The location of the MT prohibits growth of radiators in the +X direction, and the PIT prevents growth in the +/– Y direction. The option of extending the radiators in the –X direction at the current baseline location is being investigated.

The minimum impact approach to increasing the capabilities of this system consists of ORU replacement and retrofit of the TCS equipment (i.e., pump module assembly, thermal radiator rotary joint, radiator panels). One "brute force" option that is under consideration would place growth radiators and equipment on growth structure. The specific details of the options available are currently being investigated through an advanced study at JSC. The main potential impact to the baseline is, once again, preserving volume for the growth equipment and structure.

Thermal Control System Growth

- **PRD Rev D Requirement**
  - 3.4.5.4.5 The thermal distribution system shall allow for growth compatible with heat rejection requirements from EPS plus parasitic and metabolic loads (Table 3.3–3)
- **Additional radiators on the baseline PIT is not a viable option**
- **Minimum Impact Approach**
  - Upgrade Pump Module Assembly (PMA)
  - Retrofit Thermal Radiator Rotary Joint (TRRJ) / radiator panels and (optionally) add heat pump, or;
  - Install additional TCS radiators and equipment on growth structure
- **Potential Baseline Impacts**
  - Accessibility and fluid disconnects for TRRJ, PMA, and radiator panel upgrades (all ORUs)
  - Fittings for structural augmentation to PIT
  - Room for the addition of growth fluid lines

Pressurized Volume Growth

The intent of this requirement is ensure that the Space Station design allows for the expansion of the module pattern via laboratories, habitats, resource nodes, airlocks, ACRVs and log modules. The need for this requirement is driven by the results from numerous utilization analyses based upon accepted user mission data.

The minimum impact approach to implementing growth of the module pattern would defer the work until post–EMC. This is true not only for the pressurized canisters, but also the common berthing mechanisms and utilities required for installation of the elements. The critical impact to the baseline design is the reservation of volume, both internal and external, for the elements and supporting utility lines. More specifically, for the elements, node ports need to be made available for future use as a module path. The utility line issue is somewhat more complicated. Not only is volume required for the growth lines, but also a means of connection to these lines.

Pressurized Volume Growth

- **PRD Rev D Requirement**
  - 3.4.5.4.1 The SSMB design shall allow for the addition of pressurized elements such as laboratories, habitats, resource nodes, airlocks, ACRVs, and logistics modules
- **Minimum Impact Approach**
  - Add pressurized volume for growth post–EMC
  - Defer installation of growth common berthing mechanisms for module interconnect
  - Defer installation of utility lines to resource node ports for growth pressurized volume
- **Potential Baseline Impacts**
  - Ensure availability of resource node ports via equipment relocation (e.g., logistics module relocated to growth nodes)
  - Reserve internal volume in nodes/standoffs for growth utility line runs and provide a means of connection to these lines

Truss Structure Growth

The intent of this requirement is to ensure that the baseline Pre–Integrated Truss can accommodate the addition of growth structure along and orthogonal to the transverse boom. It also allows for the addition of the growth utilities associated with the increase in resources.

Structure added *along* the transverse boom will be required for accommodating growth power modules. Structure will be added *orthogonal* to the transverse boom to accommodate additional subsystems, spares storage, utilities, technology payloads, and EOS and/or spacecraft servicing facilities. All structure will be added only when needed after PMC.

Truss Structure Growth

- **PRD Rev D Requirement**
  - 3.4.5.4.2 the SSMB structural design shall allow for addition of power generation capability along the transverse boom, addition of truss orthogonal to the transverse boom, and for utility distribution associated with growth resources

- **Minimum Impact Approach**
  - Add structure orthogonal to the transverse boom post–EMC
  - Augment the transverse boom along the Y–axis for power system growth post–EMC
  - Defer utility lines for growth

Truss Structure Growth (Cont.)

The addition of structure in either mode will be possible only if fittings and connectors, as well as volume, are provided in the baseline configuration. Langley is currently identifying the configurations for the phases of the station beyond PMC. Studies are also underway that are addressing the issues of transition structure, loads analysis, and growth utility placement and support.

Truss Structure Growth (Continued)

- **Potential Baseline Impacts**
  - Provide fittings at specified locations to allow the attachment of structure orthogonal to the Pre–Integrated Truss (PIT)
  - Provide fittings and connectors at the ends of transverse boom for power augmentation
  - Reserve room along faces of the transverse boom for utilities
- **Structural loads analysis has not been completed (baseline or growth)**

EVA Systems Growth

The EVAS growth requirement states that "the SSF design shall allow for upgrade to a station–based EVA capability using an on–orbit serviceable EMU". Work is being done through the advanced studies program that will trade competing EMU life support technologies and candidate configurations, and identify highly probable growth paths. Potential growth paths include support of an on–orbit serviceable high pressure (3500 psia) oxygen system, on–orbit hydride–based heat rejection systems, and data interfaces necessary to support automated checkout and servicing of an advanced EMU.

The minimum impact approach to fulfilling the requirement is to defer installation of the EMUs and the associated support equipment and hardware. Volume for this growth equipment needs to be identified and reserved during the baseline design of the airlock. More important, however, are the penetrations in the airlock shell and MM/OD shielding that need to be drilled during the initial manufacturing process. Several of the growth scar airlock shell penetrations currently exist in the baseline design (i.e., 900 psia O_2, low pressure H_2 supply, 100–200 psia H_2, 120 VDC, and 1553 data bus), but others remain to be baselined (i.e., 62/35 °F cooling supply and the cooling return).

NASA — FREEDOM

EVA Systems Growth

- **PRD Rev D Requirement**
  - 3.4.5.4.6 The Space Station Freedom design shall allow for upgrade to a station–based EVA capability using an on–orbit serviceable Extravehicular Mobility Unit (EMU) (Table 3.3–3)
- **Minimum Impact Approach**
  - Defer advanced EMUs and associated support equipment and hardware in baseline airlock
- **Potential Baseline Approaches**
  - Volume and structural interfaces for growth hardware mounted external/internal to airlock (e.g., Advanced EMU, SPCS, O_2 and H_2 compressors)
  - Utility penetrations (O_2, H_2, power, data, thermal) and connectors in baseline airlock shell and fixed MMOD shielding

Data Management System Growth

The purpose of this requirement is to ensure that the Data Management System (DMS) is designed such that future upgrades, either functional or technological, will not require a major redesign of the system. This is the only system which is recognized by the PDRD as being evolutionary in nature. The following sections in the PDRD support this "open architecture" design: 3.2.5.1.1, 3.2.5.1.1.17 and 3.2.5.6.1.

Data Management System Growth

- **PRD Rev D Requirement**
  - 3.4.5.4.3 The SSF design shall allow for growth in data processing throughput and function, data storage capacity and performance, and network communication bandwidth by providing expandable and upgradeable system designs
- **The PDRD recognizes the evolutionary nature of this system**
- **Linkages between the PRD and PDRD have been identified for this requirement by ARMS**

Next Step

An extended version of the *Evolution Design Requirements and Design Strategy* pitch was presented at the Director's Management Review in Reston on June 16. This was the first step towards getting down to the level at which baseline detail design occurs. Meetings to discuss the work that is being done in support of evolution and review the draft CR to the PDRD at the Work Packages have been, or are being, scheduled. One task that needs to be performed by Level III is an assessment of the evolution capability of the baseline design at the Permanently Manned Configuration. LaRC and the Advanced Study task managers will be involved in a supportive role with the assessment and will ensure that there is complete flow–down of the evolution requirements to the Level III documentation.

Next Step

- **Work Package visits to review draft PDRD Evolution Requirement CR**
  - Work Package 1 – August 12
  - Work Package 2 – TBD
  - Work Package 4 – August 20

- **Support WP assessment and flow–down of requirements into Level III documents**
  - Assessments must be performed at the detail design level
  - LaRC and Advanced Studies task managers available for support

Space Station Freedom Evolution Quotes

Numerous statements concerning the capability of Space Station Freedom to evolve are being made both inside and outside the agency. Extensive analysis has been performed in support of identifying those resources that are critical for evolution of Freedom, and work is currently underway that will determine the follow–on and evolution phase configurations for the station. A considerable amount of these studies have been done from outside of the "work package baseline design process". To ensure Space Station Freedom retains the capability to evolve, the results of these studies need to be factored into the Level III work that is being done on the baseline design.

Space Station Freedom Evolution Quotes

"We realize the value of retaining a growth capability and have done so wherever possible"

– Draft testimony for the FY '92 SSF Budget hearing

"The NASA response to the 90–day assessment will include a capability growth strategy beyond the initial phase"

– 1/91 Lenoir letter to Congress

"The design should not preclude future expansion in structure, power and crew size to enable its evolution..."

– 12/90 Aldrich memo to Lenoir regarding restructuring

" We fully expect that as we build this station we will, in time, meet the requirements of the principal scientific research..."

– 3/91 Fisk statement in response to NRC, SSB criticism of the restructured PMC design

OMIT TO END

AUTHOR INDEX

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1991	Conference Publication

4. TITLE AND SUBTITLE
Beyond the Baseline 1991 - Proceedings of the Second Space Station Freedom Evolution Symposium

5. FUNDING NUMBERS

6. AUTHOR(S)
NASA and support contractor personnel funded under the Transition Definition line item - UPN 488

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Space Station Engineering Division
NASA Headquarters
Washington D.C. 20546
MC: MT

8. PERFORMING ORGANIZATION REPORT NUMBER
S-653

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington D.C. 20546

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
CP 10083

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified - unlimited

12b. DISTRIBUTION CODE
Publicly Available

13. ABSTRACT *(Maximum 200 words)*
This report contains the individual presentations delivered at the Space Station Evolution Symposium in League City, Texas, on August 6, 7, & 8, 1991. Personnel responsible for Advanced Systems Studies and Advanced Development within the Space Station Freedom Program reported on the results of their work to date. The results of SSF Advanced Studies provide a road map for the evolution of Freedom in terms of user requirements, utilization and operations concepts, and growth options for distributed systems. Regarding these specific systems, special attention is given to: highlighting changes made during restructuring; description of growth paths thru the follow-on and evolution phases; identification of minimum-impact provisions to allow flexibility in the baseline; and identification of enhancing and enabling technologies. Products of these tasks include: "Engineering" fidelity demonstrations and evaluations of advanced technology; detailed requirements, performance specifications, and design accommodations for insertion of advanced technology; and mature technology, tools and applications for SSF flight, ground and information systems.

14. SUBJECT TERMS

15 NUMBER OF PAGES

16 PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18 SECURITY CLASSIFICATION OF THIS PAGE	19 SECURITY CLASSIFICATION OF ABSTRACT	20 LIMITATION OF ABSTRACT
U	U	U	